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POTATO PRODUCTION

By

GEORGE STEWART

Potatoes were the first crop planted in Utah. In July, 1847, the Mormon pioneers turned the water from City Creek over the parched land near what is now the center of Salt Lake City. The ground was then broken and sown at once to potatoes. Only a small yield was obtained but this helped materially to eke out the meagre food supply until the harvest of 1848. During the several hard years that followed, potatoes were among the most important foods for the pioneer settlers. **Since then, they have held** a prominent place in the agriculture of the State. Just now the acreage is rapidly increasing.

No other vegetable is so widely grown and so regularly consumed for food. The high acre-yield and the relative ease of cultivation make it a profitable crop both for home consumption and for market. Responding readily to the intensive cultivation that must accompany high-priced land and irrigation, potatoes are an ideal food crop for the intermountain country. Not only for human consumption but as feed for livestock, they possess great intrinsic value. Considerable quantities may therefore be produced even at long distances from market or from the railroad.

Natural adaptation and long experience in growing potatoes have made production successful. This is reflected in the regularly increasing acre-yields. There is, however, vast room for further improvement. Better preparation of seedbeds, more careful seed selection, better methods of disease control, and wiser irrigation are all comparatively simple and inexpensive; yet they would greatly increase both the yield and the quality of Utah's potato crop. This is true not only on farms that grow potatoes almost entirely for home consumption but on those farms which grow truck potatoes for city markets and also on those which produce sufficient quantities of the general crop for interstate shipment. All growers in the intermountain states can improve in some phase of potato production and most of them in several. No known region has yet made such progress in potato-growing as to have no more lessons to learn. To this rule the farmers of Utah are not an exception.

POTATO-PRODUCING REGIONS

Altho native to America, potatoes are now produced in greatest abundance in Europe, where from 80 to 90 per cent of the world crop is grown. Most of the other 10 to 20 per cent is produced in the United States, Canada, Asiatic Russia, Japan, and Australia. In order of importance the producing nations rank as follows: (1) Germany, which produces about one-third of the world's crop, (2) European Russia, (3) Austria-Hungary, (4) France, (5) United States, (6) United Kingdom, (7) Belgium, (8) Netherlands, (9) Spain, and (10) Canada.

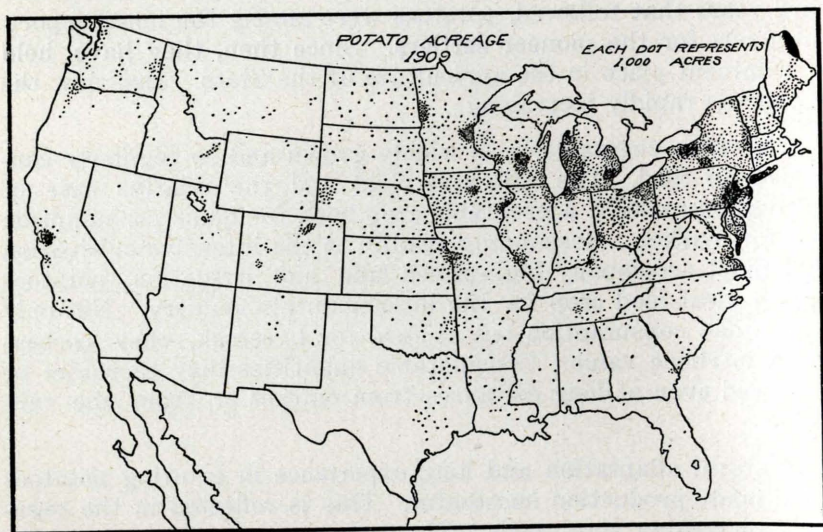


Fig. 1.—Map showing the potato-producing areas of the United States in 1909. (after U. S. D. A.)

Because of their high water content (about 78 per cent) and their perishability, potatoes are not important in the foreign trade of any country. Even Germany consumes all of her enormous crop. The United States has practically no foreign commerce in potatoes: as an average for twenty years the exports amount to barely more than a million bushels annually, and the imports to slightly more than two million bushels. Most of the exports and imports are due to convenience in transportation rather than to the operation of the laws of supply and demand.

Table I. The ten-year average acreage, acre-yields, production, farm price, and farm value of potatoes for the ten leading potato-producing states, for Utah, and for the whole United States (1908-1917)

STATE	Average Acreage (Acres)	Average Acre-yield (bushels)	Average Production (bushels)	Average Farm Price Dec. 1 (cents)	Average Farm Value Dec. 1 (dollars)
New York	383,800	93	36,026,100	82	26,853,700
Michigan	345,500	90	31,274,400	64	17,938,900
Wisconsin	283,900	99	28,338,400	60	15,552,200
Maine	128,300	205	25,741,600	71	17,452,100
Minnesota	235,000	100	24,007,500	58	13,310,000
Pennsylvania ..	284,300	83	23,609,100	84	19,473,200
Ohio	167,300	82	13,745,800	85	10,796,800
Iowa	150,200	80	12,158,900	80	8,671,400
Illinois	141,400	75	10,721,200	89	9,161,800
Virginia	105,600	92	10,034,200	84	9,194,900
Utah	20,600*	162†	3,369,400*	78†	2,682,800*
United States..	3,704,400	95.9	356,125,200	76	266,114,800

*Five-year average (1913-1917).

†Ten-year average (1908-1913).

Utah's average production is 3,369,400 bushels. This is about one third as great as the production of California, two fifths as great as that of Colorado, three fourths that of Idaho, twice that of Wyoming, and twenty times that of Arizona. The state of New York alone produces nearly as many potatoes as all the intermountain states with California excluded. Maine and Minnesota together produce almost exactly the same number of bushels as the eleven intermountain states,—approximately fifty million bushels. Utah's production is only about one tenth as great as that of New York or Michigan, and one eighth that of Minnesota, Maine, or Pennsylvania.

Potato production has developed rather rapidly in the West, as regards both acreage and acre-yields. The acreage in Utah increased from less than 9,000 acres in 1882 to more than 12,500 in 1889. Then, probably due to an era of poor prices, the acreage decreased to between 5,000 and 7,000 acres during the period from 1889 to 1900. Then came a rapid increase. There were 5,500 acres in 1900, 15,000 in 1909, and 23,000 in 1917. Acre-yields have also increased, of course, not regularly year after year, but rather uniformly if longer periods are considered. Statistics are available for the 36 years from 1882 to 1917. If these be divided into four 9-year periods—1882-1890, 1891-1899, 1900-

1908, and 1909-1917,—the average acre-yields are 87, 124, 140, and 169 bushels, respectively.

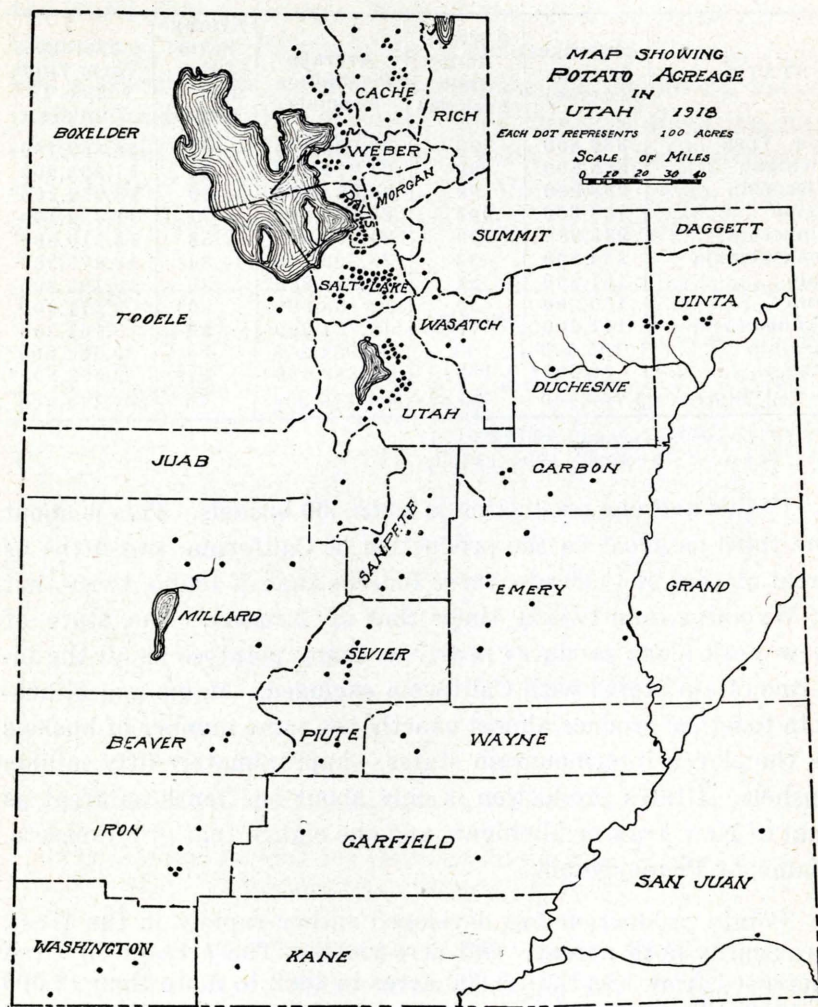


Fig. 2.—Map showing potato-producing sections of Utah in 1918.

Rapid, however, as has been the development of the potato industry in Utah, it has been even more rapid in Idaho, Colorado, and Washington. California developed much earlier, but has also shown a rapid increase in acreage since 1882, when Utah's statistics were first reported separately.

THE PLANT

History.—The potato was growing wild in the valleys of Ecuador when the Spaniards first visited that part of America about 1534. It was later found in Mexico and southern Colorado. This useful plant made its way into Virginia and North Carolina in time to be carried to England and Ireland by Raleigh's expedition in 1586. In Ireland it did so well that it soon became the principal food crop; so important did it become in fact that a failure due to blight caused a general famine in 1846. During this year and the next, more than 300,000 people died of starvation and other thousands left the country. Meantime, the Indians and whites in the neighborhood of Jamestown gradually increased their dependence on the potato until, by the first of the eighteenth century, they used it generally. By the middle of that century, it had spread into those parts of Europe favorable to its growth and gained larger and larger footholds on account of its high acre-yields. In thickly populated districts, just such a food crop was needed.

Relationships.—Botanically the potato is *Solanum tuberosum*. There are about sixteen hundred species in the potato family, and nine hundred of them in the same genus, only six of which, however, bear tubers. Besides the ordinary potato, only *Solanum commersonii* is important. It is disease-resistant, but yields poorly. Among the immediate relatives of the potato is the tomato, which is so closely related that parts of one plant may be grafted on the other. Tobacco, nightshade, henbane, and belladonna also belong in the same family.

Description.—The plant originally propagated itself by means of seed, but man has propagated it by means of tubers that contain buds, or "eyes", so long that the seed is seldom or never considered. The buried "set", as the cut piece of tuber is called, sends out a stem which bears leaves after reaching sunlight. The length of this underground stem depends on the depth of planting. At various places on this stem new branches, or stolons, grow horizontally outward, some of which bear tubers at the end. From two to four roots grow from the upright stem at the base of tuber-bearing stolons.

By the time of maturity, the fibrous roots have spread for twelve or eighteen inches and have extended four or five feet into the soil if it is loose and well-drained. Tubers from one to thirty in number, varying from the size of a pea to six pounds, have been found in a single hill. Six or more potatoes about the size of the double-fist are preferred. The angular stem, which varies from one to five feet in length, with a usual height of about two

or two and a half feet, stands upright or droops across the open space, depending on the variety and on soil conditions. The leaves are compound with small leaflets growing in the axil and scattered irregularly between the thick, pointed, oval leaf-parts, which are from one to three inches long.

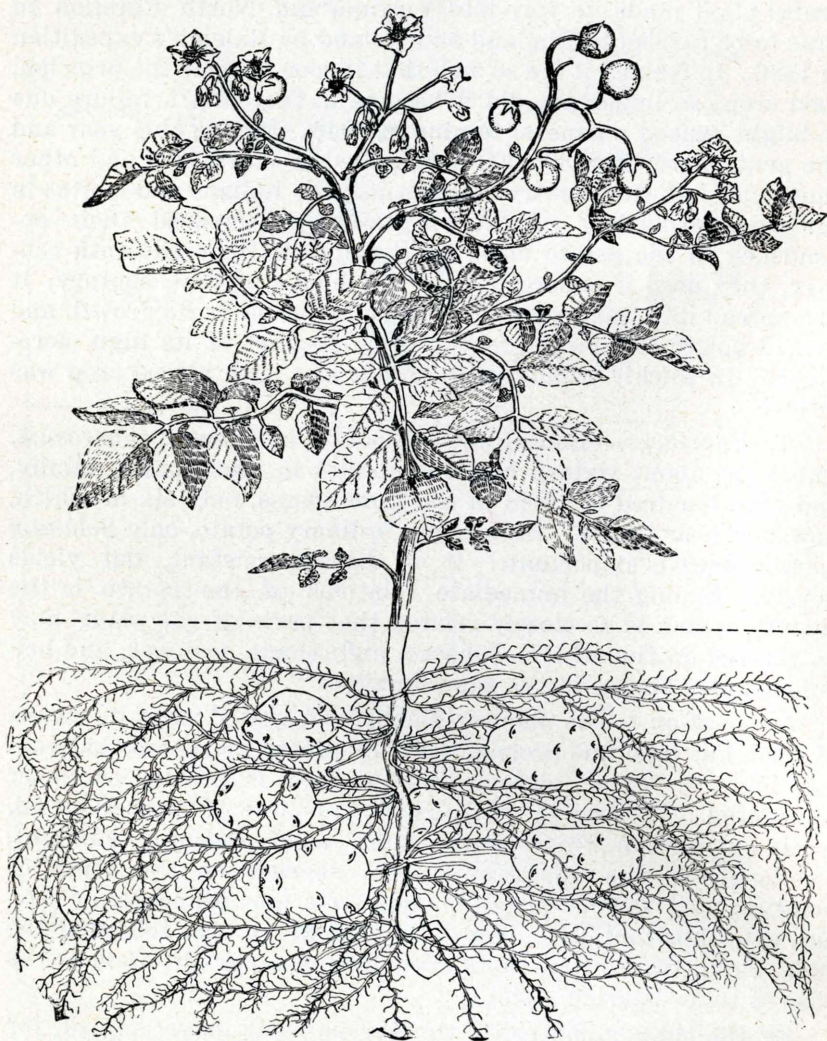


Fig. 3.—Diagram of a potato plant. Note the slender unbranched stolons on which the tubers are borne.

Buds, or eyes, are borne sparsely at the stem end and close together at the bud end of the tubers. A string passed around the tuber and held in position with a pin in each eye shows a

spiral arrangement of the eyes. Cross-sections of a tuber show three nearly concentric, and one irregular part. The outermost, the external cortical, is poor in starch and so thin as to be almost entirely removed in peeling. Then comes a thicker layer, rich in

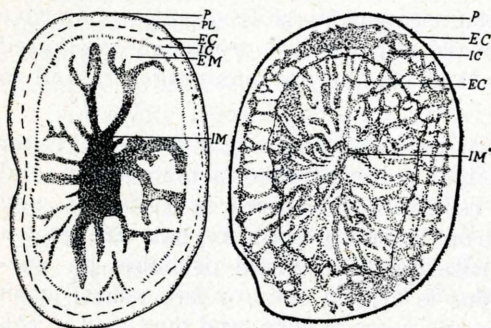


Fig. 4.—Diagram showing good quality, (right) and poor quality (left). P, epidermis; PL, pigment; EC, external cortical; IC, internal cortical; EM, external medullary; IM, internal medullary (dark colored).

gives the potato the quality of mashing readily when cooked. Potatoes that are yellow and soggy after cooking are undesirable in America, where they are usually baked or boiled, but are highly prized by the French, who serve them fried.

PLACE IN THE CROPPING SYSTEM

Potatoes may be grown in various cropping systems, if the proper soil condition exists. Tho there are many systems of crop rotation or partial rotation in Utah, general systems for three groups of farms require attention. These are (1) truck farms on which neither alfalfa nor grain is the basic crop; (2) general farms on which alfalfa and potatoes, or alfalfa, potatoes, and sugar-beets are the principal crops; and (3) farms on which grain or sugar-beets or both are the principal cash crop and on which potatoes are grown merely for home consumption. Grain is usually of small consideration in the first group, of only moderate importance in the second, but together with alfalfa, or alfalfa and sugar-beets, of primary importance in the third.

Truck farms grow neither alfalfa nor grain as a principal crop. Trucking in Utah is confined almost entirely to Boxelder, Weber, Davis, Salt Lake, and Utah counties. The land is too high-priced for grain and not much alfalfa is grown because the farms are too small successfully to compete with those that are both considerable in extent and at the same time fairly well stocked with

dairy cows or other livestock. On such farms, beans (or peas) are just beginning to be grown. These leguminous crops are necessary to keep up the nitrogen supply of the soil and to afford some semblance of rotation where alfalfa is not produced. It is probably advisable to grow potatoes only once in three or four years, altho under some circumstances more frequent crops prove profitable. In some cases beans or other late crops can be planted after early potatoes are harvested, thereby enabling the land to do double duty.

On general farms where potatoes and sugar-beets together with alfalfa form the principal crops, alfalfa furnishes hay and also serves as a nitrogen restorer; potatoes, or potatoes and sugar-beets are the cash crops; usually some cereals are grown for silage or grain. One rotation that would probably be successful under such conditions is alfalfa four or five years, corn for silage one year, potatoes one year on corn land manured in the fall, beets one year with some manure, beans one year, beets one year with manure to supplement the bean residues, and small-grain one year to serve as a nurse crop for alfalfa, or to be taken off early, and the alfalfa sown after it is harvested. If corn is not grown, potatoes could follow alfalfa, making the cropping system alfalfa, potatoes, beets with manure, beans, beets with manure, and grain. Potatoes might also be grown just ahead of the nurse crop of grain instead of beets. Some farmers grow potatoes oftener than this but in general, diseases are likely to cause trouble if this is done. A possible rotation here would be alfalfa, potatoes, beets or grain, beans, potatoes, and alfalfa with or without a nurse crop. In this case beans would serve as an additional cash crop and also as nitrogen gatherers, to break the long period between two alfalfa crops. Ordinarily, however, they are omitted.

Where only grain and alfalfa or grain, alfalfa, and sugar-beets are grown extensively, with a small acreage of potatoes mainly for home use, a still different arrangement is necessary. A possible rotation would be alfalfa five or six years, (in some sections seven or eight and in others only three or four) corn, small-grain, beans, corn with manure, or small-grain as a nurse crop. Where corn is not profitable the rotation might be alfalfa, small-grain, beans, small-grain, and a different small-grain with manure to serve as a nurse crop for alfalfa. One or two acres of potatoes, more often a half acre, may be thrown into the rotation at one of several places. Just after alfalfa is perhaps the best place. If silage corn follows alfalfa, a piece of corn land can be well manured in the fall before fall

plowing. Another good place is after beans with some manure turned under to supplement the bean residues. In this cropping system potatoes should receive the utmost care because only a small area is grown and they can fit in almost anywhere without upsetting any other crop. Some farmers find it highly profitable to plant potatoes only on land broken from alfalfa sod. Fall breaking is then of the utmost importance. Often it will be profitable to add a thin coating of rich manure to the alfalfa stubble before breaking, especially if the alfalfa is thin.

Generally there is no good reason for growing potatoes more than once in six to ten years on the same land, unless it so happens that only a small part of the farm is good potato soil. In this case it might be wise to rotate as thoroly as possible and in the meantime prepare another small area by heavy manuring, by the growth of alfalfa, or even by the addition of sand or small wood chips or sawdust, if the land is decidedly compact.

FACTORS IN PRODUCTION

Aside from the ordinary cultural operations, six major factors markedly affect potato production. These factors are (1) climate, (2) selection of soils, (3) supply of organic matter, (4) soil moisture, (5) seed selection, and (6) disease control.

CLIMATE

Climate is doubtless the most important single factor affecting potato production. Fairly good potatoes can be obtained on almost any kind of soil with ordinary cultural methods where the climate is highly favorable. On the other hand, no degree of attention to soil, seed selection, soil moisture, or fertilizing can overcome the drawback of too hot a climate. On this account practically all the potatoes grown in the United States are produced in the northernmost states except in the mountain section where high altitude largely overcomes the bad effect of low latitude. Too much cold weather, of course, is fatal.

A survey of European potato-producing countries shows that the best regions are considerably farther north than the Canadian boundary, in fact as far north as Labrador which is too cold and bleak for crops much hardier than potatoes. The warm Gulf stream, however, so moderates these European climates as to counterbalance the effect of high latitude. The seasons of Scotland, Belgium, Holland, northern Germany, and southern Scandinavia are long, moderately moist, and uniformly cool. Irregular coastal lines further accentuate this by bringing the cool, moist, oceanic climate to a much larger area than is the case with the United States. The long days of northern summer materially

increase the number of hours of daylight, and in starch production light is an important factor. It is this highly favorable climate coupled with intensive farming, intelligent seed selection, and disease control that makes possible the high acre-yields of European countries. From Scotland which represents the acme of climate adaptation, Lord Roseberry reports acre-yields of approximately 2,000 bushels. In the hotter American climates 1,000 bushels is extremely rare. The acre-yield of Belgium is 307 bushels, of the Netherlands, 269, of Great Britain and Ireland, 215, and of Germany, 205. Hotter southern, and hotter or drier interior Europe have much lower yields,—Russia 106, Austria-Hungary 136, France 125, and Spain 123. The average for the whole United States for the same period was 97.5 while Maine with a more northern and more oceanic climate grew 205 bushels an acre. The acre-yields of Montana, Idaho, Washington, and Utah, are 141, 159, 142, and 162 bushels, respectively, as against 90 bushels for New Mexico, and 101 for Arizona. The northern counties of Utah show yields as follows: Boxelder 183.2 bushels, Cache 175.4, and Rich 191.1. The hot southern counties yield much less—Grand, 83.2 bushels, San Juan 59.3, and Washington 127.2. Morgan, another cool county of northern Utah, yields 196.6. Beaver-county potatoes have been nearly all produced in a higher and therefore cooler valley. Here the acre-yield is 167.2 bushels.

Length of growing season is also important. Potatoes make most of their growth late in the season. Table II shows data from Minnesota bearing on this subject.

Table II. The yield of Early Ohio Potatoes Dug on Different Dates.

Date of Digging	Total (bushels)	Total (Marketable)	Gain (Marketable) Bu. a day	Per cent Foliage dead
July 31.....	38.7	10.9		0
August 7....	87.7	62.3	7.5	1
August 14....	141.5	115.4	7.6	8
August 23....	203.2	182.1	7.2	22
August 30....	253.8	226.8	6.4	99

Late potatoes continue their growth until well into October in some sections. Slight frosts are not so nearly fatal to potatoes as they are to beans or corn.

SELECTION OF SOILS

Potatoes thrive best on warm, porous soils that are at the same time fertile and retentive of moisture. Tho not to their best advantage on either clay or gravelly soils, they can be grown

successfully on such soils if care is taken to put them in proper condition. Mineral plant-foods are required in abundance. Phosphorus and potassium must both be readily available, the draft being much heavier on potash. With these two elements our soils are abundantly supplied. Nitrogen, which is required in moderate quantities is probably best supplied as organic matter, which improves the tilth as well as supplies nitrogen and renders minerals available. Considerable phosphorus and potassium are also carried in farm manure.



Fig. 5.—A field of good potatoes during growth.

There are, however, five rather common soil conditions in the arid West that are decidedly unfavorable to potato production: namely, (1) compact soils, (2) alkali, (3) waterlogging, (4) extraordinarily large supplies of organic matter, and (5) very coarse sands or gravels.

Compact soils cause a dwarfed vine growth. The total yield is likely to be low, and the tubers are likely to be small or knobby and irregular. Clayey and other compact soils are not porous enough to permit easy aeration. If conditions are favorable such soils are likely to be over-wet and stick in spring and hard and dry in late summer and autumn when the tubers should grow most rapidly. Both stickiness and compactness are undesirable: wet, sticky soils do not warm up soon enough, whereas hard soils do not allow the free access of air either to roots or to soil bacteria. Moreover, they are likely to crack and thereby expose the soil moisture to rapid loss by evaporation. Finally, it is difficult to maintain the moisture supply, since great compactness

in a soil both reduces its water-holding capacity and also causes additional water to be absorbed but slowly. Rapid rains are likely to run off and irrigation water either to be wasted or to be applied in sufficient quantity only at the upper end of the field.

Alkali injures potatoes markedly. Where only traces are present in the soil, the vines are slightly stunted. Larger quantities materially reduce both growth of vines and yield of tubers. When alkali salts are extremely abundant, germination is poor and growth is greatly retarded.

Waterlogging, even when accompanied by alkali, is disastrous to potatoes. If alkali be present as well, the prospect for a good yield is decidedly poor. Waterlogging shuts out air, prevents early warming, and is likely to be fatal to the helpful soil bacteria. Cultivation and harvesting will also be difficult and expensive, partly because such soils are likely to become compact in late summer or because of stickiness in the soil due to excessive moisture.

Excessive quantities of organic matter stimulate rank vine growth. This reduces the size of the tubers and also encourages disease. Thrifty vines are necessary to high yield but they ought not to be so rank that they will not stand well out of the water furrow, at least while young. Air and sunshine both aid in preventing disease and in encouraging starch production. Moderate quantities of well-decayed organic matter, however, are necessary to maintain a uniform supply of soil moisture.

Coarse sands and gravels are so porous that it is difficult to maintain the uniform moisture supply essential for high yields of potatoes. Extremely small quantities of water pass quickly through these sieve-like soils and percolate beyond reach of the roots. The temperature of such soils becomes high in the daytime on account of the high mineral content and because little water is present. Such soils encourage early maturity which counts against large yields. High temperature is also liable to weaken the vitality of the tuber buds, or eyes. It is practically impossible to get enough moisture-retaining material into such soils to make them good for potatoes unless they be treated more as mechanical mediums to hold plant-food and organic matter than as fertile soils. Only trucking systems and nearby city markets can make this kind of potato farming economically profitable.

It is apparent, then, that loamy soils are most desirable for potatoes. Such soils, while both fertile and retentive of moisture, are at the same time warm in spring and porous enough to permit aeration and drainage. Cultivation and irrigation are not too difficult, and harvesting can be effected without excessive labor.

Clay loams, sandy loams, and even fine gravelly loams may be used. A wide range of soils—most of our good soils—are adapted to potato production. Care, however, must be exercised not to employ either the extremely compact or the extremely porous types. If gravelly or coarse sandy loams are used their content of organic matter must be maintained so as to provide a moderate and uniform moisture supply. If clays or heavy clay loams are used, careful manuring and judicious cultivation must not be neglected even for one season. The puddling of such soils is fatal not only to yield but also to smoothness of the tubers.

SUPPLY OF ORGANIC MATTER

Manuring practices vary considerably. In the East commercial fertilizers are in general use, especially in the trucking sections. Phosphorus, potash, and nitrogen are frequently applied. This form of manuring has not yet become general in the West. Potato growers of Utah and adjacent states depend on farm manures and sod both for organic matter and for the fertilizing elements. Occasionally a late fall or an early spring growth of alfalfa is turned under, but the usual practice is to make hay of this and return to the land the manure made by the animals. With many cattle on the summer ranges, this is probably the most profitable system of fertilizing the land.

The function of farm manure and sod is principally to supply organic matter. In the end, complete decomposition results and the fertilizing elements are added to the soil in a readily available form. Important, however, as the fertilizing elements may be, the indirect effect is still more important. Coarse manure and large roots are hindrances to cultivation and irrigation, but under favorable conditions, these soon decompose into fine particles which mix readily with the soil particles. Organic matter in such condition is valuable in two distinct ways: (1) by increasing the water-holding capacity, and (2) by creating a condition of medium porosity in the soil.

Increases water-holding capacity.—Decaying organic matter absorbs water much as does a sponge. Because many of the particles are hollow, the surface to which films of water can cling is much greater than on solid particles of the same volume. In addition organic matter contains a substance called humic acid which has the power of holding many times its own weight of water.

Controls porosity and aeration.—Organic matter also loosens clay soils and renders them porous. It has the opposite effect

on coarse sands and otherwise extremely porous soils, in which it serves as sort of binder as well as a retainer of water.

It is common knowledge that wet sand, even if nearly pure and very coarse, will hold together with greater tenacity than the same sand when deprived of its moisture. Organic matter, therefore, consolidates loose soils both by supplying a binding agent and by furnishing a retainer of water. A high degree of looseness in clays and a high degree of consolidation in sands increase the water-holding powers of such soils. These conditions also encourage a more desirable aeration and a great uniformity of temperature.

Compact clays have too little pore space to hold much water or to permit the easy exchange of gases between the soil and the atmosphere. Roots and bacteria both need air; oxygen also helps in rendering mineral plant-foods soluble. Sandy soils are likely to be too hot and clayey soils too cold. The extra moisture and the consolidation in sandy soils moderate the temperature of these soils and thereby decrease evaporation. In heavy soils the increase of pore space encourages more thoro ventilation. As the water content increases to about medium the pore space increases. If more water is added the volume decreases and consequently the air space. It is at this point of greatest volume that soils aerate most readily and consequently maintain the most uniform temperatures. Roots can penetrate a soil in this condition more easily and more deeply because air is available at greater depths and because there is less resistance. In all respects the soil is then in the most favorable condition for plant growth. When such a desirable soil condition is reached, it is said to hold an optimum (Latin, meaning "the best") water content. Actively decaying organic matter tends to bring all soils to this desirable condition.

SOIL MOISTURE

The quantity of moisture in a soil at planting time depends largely on the amount and distribution of rainfall, on the nature of the soil, on the previous crop in the rotation, and on the manuring practice. Preparation of the seedbed and subsequent cultivation likewise have considerable influence. Fall plowing permits the more ready absorption of winter and spring rainfall. Spring disking, harrowing, and weed control preserve the moisture for use by the crop. After the crop has begun growth, it is merely a question of time until the available supply in the soil becomes exhausted or so nearly so as to prevent thrifty and rapid growth. Irrigation, which then becomes necessary, is discussed under a separate heading. If possible the seedbed

should contain enough moisture to germinate the seed sets and give a good stand.

SEED SELECTION

Since some varieties of potatoes have much higher yielding possibilities than others, the variety chosen is important. One disturbing factor in choosing potato seed is that some districts cannot use home-grown seed. The North ships to the South practically all the seed used there. Arizona also imports seed potatoes. In the West, some growers have small farms in mountain valleys which furnish seed for their large farms in lower valleys, but in most cases selected home-grown seed is the best.

Sometimes varieties deteriorate, or "run out." This need not happen if proper selection is practiced. There is a tendency to use or sell all the marketable potatoes, thus leaving the small ones for seed. Potato hills vary widely not only in the number of potatoes they produce but also in the kind. Some hills have from four to eight tubers of much the same size and shape, containing no extremely large ones and no small ones; others contain one enormous potato and a number of small ones; still others consist almost entirely of small tubers. Since both very large and very small potatoes are undesirable for market purposes, hills with a fair number of medium-sized tubers are most desirable.

A set from any potato in the hill tends to produce a hill like the parent hill. A big potato from a poor hill is not as good as a small one from a good hill. It seems that any potato in a hill is as good for seed as any other. If such is true there is no objection to using the small potatoes from desirable hills if they are known to be such. It is bad practice, however, to use small potatoes from the cellar or from the grading machine because most of them are from undesirable hills.

DISEASE CONTROL

Disease control is closely related to the selection and the treatment of seed. It is also closely related to the cropping system because most of the diseases troublesome to potatoes live in the soil for four or five years, possibly for a longer time. Potatoes ought not, therefore, to be planted on the same land oftener than once in five years unless the necessity for doing so is really great. Greeley, Colorado, once famous for potatoes nearly abandoned the crop for several years following 1911 because of disaster due to constant cropping. The crop is again increasing but is now being grown under much more careful cultural and rotation practices. Moderate irrigation, fall plowing,

and wise manuring also aid considerably in the control of potato diseases. Under another heading are described the troublesome potato diseases occurring in the West. Resulting damage and control measures are also there given.

PREPARATION OF THE SEEDBED

Preparation for irrigation.—Long before the plowing season approaches, land should be prepared for irrigation. This is not as simple as it may seem. In the first place head-ditches for delivering the water and the necessary distributing ditches leading out from these must be made. Since potatoes will, in practically all cases, be irrigated by the furrow system, it is necessary to determine first the direction in which water is to run. Ordinarily this problem is sadly neglected. Because many of our farm lands slope in two or more directions, it is possible to run furrows in any one of several directions: straight down the field from end to end, straight across from side to side, or at various diagonals. Since potato roots offer little resistance to washing, the slope ought not to be exceptionally steep. Badly rutted furrows permit rapid evaporation and also render both cultivation and harvesting inconvenient. Besides, such a practice is also responsible for the carrying away of the finest particles which are either organic matter or the soil particles richest in plant-food. Neither must the slope be too gentle for this will encourage flooding across from one furrow to another, thereby leaving the ground too wet for potatoes.

Sometimes the land is naturally uneven or has been made so by silt deposits near the inlet head-ditches on alfalfa or other fields that have been cropped for a long period without plowing. Erosion channels and "dead furrows" too often give an uneven surface in many of the best fields. The wise plowing of "double" furrows, the proper dragging after plowing, and the judicious location of distributing head-ditches will usually overcome slight irregularities of surface. If, however, the land is badly roughened, it is highly profitable to level with plow and scraper before plowing. This not only saves labor in irrigation but enables the irrigator to distribute water evenly, thereby increasing the efficiency of both land and water. After any considerable filling of low places, enough time should elapse before plowing to allow the loose earth to settle to its permanent level. This avoids low places that will form pools during irrigation.

Manuring.—Farm manure for potatoes may be applied to a previous crop such as corn, beets, or garden stuff. It may be

added as a thin coating after beans or on alfalfa or grass sod previous to breaking. Another practice that is gaining favor among successful growers is the fall or winter application of manure on fall-plowed land. Turning under in the fall is preferred, but to leave the manure on the plowed ground all winter to be worked into the soil in spring with a disk is also counted satisfactory. If the land is not fall plowed, it is still good practice to apply the manure in the fall or during the winter, even on top of snow. Unless the land is steep and compact, so badly eroded as to form channels, or frozen under the snow there will be little loss from the carrying away of manure in the run-off when the snow melts. Land manured in this way is best plowed as early as possible in spring.

If for any reason fall or winter application is not made, the manure should be added at the earliest possible time in spring. It is also advisable not to use manure containing much coarse straw or cornstalks for spring applications unless no other manure is available. The turning under of coarse manure at the same time that the potatoes are planted is still more uncertain, especially should a dry period follow planting. Poor stands and delayed growth are likely to result. Besides, potato scab is encouraged by an abundance of coarse manure. Finally, irrigation and cultivation are more difficult than when the manure is sufficiently decomposed to be readily incorporated with the soil particles.

Moderate quantities of manure have given better results for ordinary potato crops than either very light or extremely heavy applications. Truck farms sometimes apply 40 to 60 tons of fresh manure to the acre, but 15 or 20 tons is likely to be more satisfactory for general farming. The manure should be scattered over the land at the time it is being hauled out and spread as uniformly as possible. In these respects, manure spreaders are more efficient than hand labor. Making small piles to be scattered at another operation is wasteful of labor. Since this practice prevents uniform distribution, it is also wasteful of manure. Much of the fertilizing elements is leached into the soil directly beneath the pile, leaving only the resistant remnant to be scattered, especially if these piles are left for any great length of time. Horse and sheep manures deteriorate more rapidly in piles than do cattle and hog manures.

Breaking.—For potatoes following alfalfa, the land should be broken in the fall to permit settling and to allow time for partial decomposition of the coarse roots. The practice of crowning before plowing is spreading. This consists of plowing to the depth of three or four inches to cut off the roots just below the

crowns. When these crowns are thoroly dry, the plowing is done at the depth desired. Adherents of this practice maintain that fewer of the roots begin growth to cause trouble in intertillage the next season. Frequently crowning is done in the fall and plowing early the next spring. Where breaking cannot be done until spring, it needs to be done thoroly and just as early as the soil condition permits. It may also be necessary to use compacting implements to conserve moisture and to promote decay.

Plowing should take place in the fall unless this is markedly inconvenient. With a late-planted crop such as potatoes it is easy to neglect fall plowing even when other work is not crowding. With potatoes as with beans and beets, this should not be allowed to happen except under unusual circumstances. If for any reason plowing is to be left until spring it is advisable in the fall to work stubble and other residues into the soil with a disk. This is also a good practice when manure is applied in autumn and is not to be turned under until spring.

Plowing, like manuring, is best done early whether in fall or spring. In no case should potatoes be planted immediately after plowing. Poor stands are likely to result unless enough time is allowed for the soil to settle into a firm seedbed. Eight or ten inches is probably the best depth to plow. Shallower plowing often fails completely to cover manure or plant residues whereas deeper plowing is likely to be too expensive in both time and horse labor.

✓✓ Fall-plowed land, except where the blowing of the soil is troublesome in winter, should be left rough without harrowing or dragging of any sort. This gives the frost a chance at the clods, insects, and plant diseases. Fall, winter, and early spring rainfall can also pass at once into the subsoil there to be stored for the growing season. Because fall-plowed land will settle enough during winter, it is not necessary to use packing implements such as the disk or culti-packer unless this is desirable for some other reason. As soon as the land dries enough to bear the horses in spring, the harrow or disk should be used to smooth and mulch the surface.

Harrowing.—To get the best results from spring plowing not only must it be early, but it should be followed each half day with a spiketooth harrow or with an equivalent implement. If the land is cloddy or if much coarse organic matter is turned under, it may be wise to use the disk or the culti-packer to pulverize clods or to firm the sub-surface in order to promote decay.

Other harrowings may take place advantageously. These will break up any crust which might form and will mulch the surface

besides further firming the seedbed beneath and pulling out weed seedlings before they can become established. This is the most economical time to kill weeds because wide implements may be used and because the weeds are killed by slight scratching. Should the soil be badly infested with weed seed, this cultivation will bring them to the surface where they can germinate and be killed by the next cultivation. If the seedbed contains many weed seedlings when the time for planting has come, a final harrowing should precede the planter. In spite of all that can be done weeds sometimes get too large for the spiketooth harrow. The springtooth or disk harrow must then be used. The farmers of the Pacific Northwest use a rod weeder. This is merely a rod about an inch in diameter fastened on wheels in such a way that it can be let below the surface. Some "brands" of the machine have cogs to give the rod a rotary movement. This prevents clogging due to weeds catching on the rod. It is particularly well adapted for clearing fallow land of weeds.

VARIETIES

Varietal names of potatoes are in a muddle. Several hundred names occur in the country but there are by no means that many varieties. Many names are often attached to the same variety and the same name to several varieties. In the intermountain section for example, Burbank potatoes have been found bearing the names Burbank, Russet Burbank, Russet, Netted Gem, Netted Burbank, Russet Gems, Idaho Gem, Idaho Russet, and Brown Beauty. Doubtless there are many other names for this variety, but this list serves to illustrate the unfortunate condition. Names are easily forgotten and just as easily added. It is easy to name a potato from a successful grower, from a locality, or from some striking character, such as the netted or russet character in the Burbank. Seedsmen often find it to their advantage to rename an old variety.

William Stuart, potato expert for the United States Department of Agriculture, found that all the varieties grown in the United States might be put into eleven groups, or composite varieties. These groups are distinct, but further classification within the group was found to be not only difficult and uncertain but not particularly valuable, since each group is essentially alike. These so-called varieties may be regarded merely as strains of the real parent variety, the group. The eleven groups are (1) Cobbler, (3) Triumph, (3) Early Michigan, (4) Rose, (5) Early Ohio, (6) Hebron, (7) Burbank, (8) Green Mountain, (9) Rural, (10) Pearl, and (11) Peachblow. Of these eleven

Utah grows seven, but only four in considerable quantities. These four are Early Ohio, Burbank, Rural, and Pearl. A few Cobbler and Green Mountain potatoes are grown and some quantity of Rose.

The Rural group is at present the most important, altho the Burbanks are gaining rapidly in some sections. Rurals are grown all over the state for the late crop. Many names occur, some of the most common of which are Mortgage Lifter, Majestic, Rural New Yorker, Eureka, Idaho Rural, Freeman, and Rural. These varieties are flat-oval and have whitish russet-colored skins and yellowish-white flesh. When they begin to grow, the sprouts have a splash of blue or purple. The flowers are also likely to have a bluish tinge.

Burbanks are readily detected by their characteristic long shape and deeply russeted skin. They have compound eyes which under unfavorable conditions tend to develop into knobs. The common names under which this variety occurs are Burbank, Russet Burbank, and Netted Gem. Smooth Burbanks are perhaps the most popular market potatoes. For the last two or three years on several local markets they have brought slightly higher prices than other varieties. Their deep russet color and good keeping qualities are partly responsible for this bonus.

Green Mountain potatoes greatly resemble Rurals, except that the tubers are oblong-flat rather than flat-oval. The color of skin and flesh is the same but the sprouts, flowers, and stems of Green Mountain bear no splashes of blue or purple. Green, yellow, light brown, and white are the only colors occurring in any part of the plant or tuber. Because of this lack of blue, they are often called "white sprout" potatoes to distinguish them from the "blue sprout" Rurals. Whether the blue has anything to do with it is not known, but the Rural is considerably more heat-resistant than is the Green Mountain. A few splendid fields of Green Mountain potatoes are grown in the state but usually in high valleys or in locations cool for some other reason. This group is not widely spread. It occurs as Beauty, Majestic, Queen, Green Mountain, and Idaho Rural, which name is attached to both Rural and Green Mountain potatoes.

Early Ohio is the principal early potato of the trucking sections. It is reddish, elliptical-round, and has compound eyes which tend to develop knobs when grown under unfavorable conditions. It is usually called by its right name though it is known as Red Willard in some localities.

Other early potatoes are Early Rose and Early Eureka, the latter of which is a Cobbler. The Early Rose is long, reddish, and has many and deep eyes. The Early Eureka is white, deep-

eyed, and tends to be cubical. It tends also to get coarse with an abundance of soil moisture and organic matter. It then becomes medium late instead of early.

Pearls resemble Rurals except that the eyes are more grouped at one end and that they tend to be coarser. Pearl, Peerless, and People's belong to the Pearl group. This variety is not nearly so popular as formerly, at least in sections where good strains of Rurals or Burbanks have been grown for any great length of time.

Just which variety to grow must be decided by the individual farmers. For most Utah valleys of 4,500 feet elevation, or thereabouts, Rurals and Burbanks seem about equal for late potatoes. In the cool sections the Green Mountain may be added. Early Ohio seems to be the most popular early potato, tho many Early Rose fields are found. Early Eureka has the advantage of white skin and somewhat higher yield, but is not quite so early. The important thing in choosing a variety seems to be to get a well-selected strain and to grow only one early and one late variety unless special markets require more. Early potatoes mature in about one hundred days and late ones in about 130 days. Early potatoes are often dug before maturity in order to take advantage of high prices.

A variety much grown in Utah twenty years ago is the Meshanock. It had bluish skin, blue markings in the flesh, many and deep eyes, and a tendency to become rough. It is now almost entirely replaced by more desirable market potatoes. Many farmers, however, grow a few rows for home use. They maintain that this variety has better cooking qualities than have other varieties, and that it is more resistant to disease. Experimental evidence on both these questions is lacking. Its color, roughness, and mediocre yield doomed it as a market potato, altho for home use it will probably persist for a long while in some sections.

DISEASES

Each year Utah potato-growers suffer enormous losses due to disease. Careful estimates place this loss at 10 to 15 per cent, that is, about \$200,000 to \$300,000 on a crop worth about \$2,000,000. The diseases responsible for most of this trouble are Rhizoctonia, Fusarium wilt, scab, and blackleg. Early blight, tipburn, mosaic, and others cause loss to an unknown extent. Station plant pathologists think Rhizoctonia causes a loss of about \$100,000 annually; Fusarium wilt, another \$100,000; and all the others \$100,000 more. Tho only estimates, these figures are suggestive of great gains made possible by effective disease

control. Pathologists think at least half of the damage can be so prevented.

DESCRIPTION

These diseases all attack the growing vines in the field. In addition, *Fusarium* and blackleg cause tuber rots which affect the potatoes in storage.

Rhizoctonia (caused by *Corticium vagum*) is a fungus that lives over in the soil and on the tuber as small specks. These specks vary in size from that of pin point to that of a kernel of corn. They look like spots of dry mud, but when dipped in water, instead of washing off they become jet black and remain fast. Under the microscope these specks prove to be threadlike mycelia of the fungus in a compact, dry mass.

The mycelial threads germinate about the time the potato sets sprout. They grow into long threadlike strands which wind around the young stems and stolons and kill the softer tissues. If conditions are favorable to the disease early in the season, the stems are so badly injured as to be stunted or even killed outright. Many stolons are cut off, preventing the formation of tubers. In older plants, the inner tissues become too woody to be destroyed; consequently only the softer outer tissues are killed. The tubes up which water of the potato plant goes from the roots are imbedded in the woody interior, whereas the tubes that carry food from the leaves where it is manufactured to the tubers where it is stored are in the outer, soft tissues. Older plants injured with *Rhizoctonia* may look green and fresh but the tubers do not grow rapidly because the food stream does not reach them. The vines have large quantities of extra starch that normally goes to the tuber for storage. Clusters of new leaves form in the axils of the normal leafstalks. This gives rise to the term "rosette" disease. Occasionally, small tubers form above ground on the vines. Growing in the light, these abnormal potatoes become green by developing chlorophyll. They are, therefore, valueless for food. The base of the main stem is covered with brown strands and is usually shriveled.

Fusarium wilt (caused by the fungus *Fusarium oxysporum*) is another disease causing as great if not greater loss than does *Rhizoctonia*. It lives over in the soil and inside the tuber. A slice one-eighth of an inch in thickness cut from the stem end of the tuber shows its presence as brown or dark spots. When the sets sprout, the fungus begins to grow and, entering the water tubes of the stem and stolons, clog them up. Bad attacks cause wilting even when the ground is moist. Whole fields of healthful-looking vines have wilted down, turned brown, and died inside of a week. More commonly, however, the plants wilt,

turn brown by degrees, and become unthrifty, dying three or four weeks ahead of the time for normal maturity.

Yields are of course decreased markedly; the cooking and keeping qualities of the potatoes are also impaired. Badly infected tubers will not meal up when mashed after cooking. The fungus causes a hard, discolored mass. An accompanying relative of this fungus also causes "dry" rot which is a serious storage disease, spreading as it does rapidly through the whole bin of potatoes.

Common scab (caused by the bacteria Actinomyces chromogenus) lives in the soil and on the tuber is a scabby pit, from which it gets its name. Scabby potatoes are not injured for cooking except that extra waste is necessary in peeling. Yield is not materially affected but badly scabbed tubers are so unsightly as to be unfit for market. Mechanical scratching or wounding of the tuber also causes a scabby appearance.

Blackleg or blackstem rot (caused by Bacillus phytophorus) is a bacterial disease that attacks the young vine and the tubers in the field. The stem is black from the set to two or three inches above ground. The plants are killed or dwarfed, the leaves have a tendency to roll about the midrib, and the whole plant looks upright and scrubby. The tuber is likely to show dark spots or interior areas of soft rot that are black and foul-smelling. The disease spreads rapidly by means of infected seed and possibly by means of cultivating machinery and irrigation water. It is now spreading rapidly in Utah.

Other diseases causing trouble are early blight, tipburn, and mosaic. Early blight can be identified by brown spots on the leaves showing as target-like concentric rings. Tipburn shows irregular brown areas at the tip of the leaf and along the edges. It can be distinguished from early blight by its lack of concentric rings. Mosaic disease shows mottled areas of light green or whitish.

CONTROL MEASURES

Rotation of crops is necessary because Rhizoctonia, Fusarium, and scab live four or five years in the soil. Other plants assist in carrying them along from year to year. Fusarium lives on the tomato, ground cherry, and other related plants; Rhizoctonia lives on redroot pigweed, ground cherry, Russian thistle, sugarbeets, and some other plants. Clean cultivation and thoro rotation are, therefore, necessary in combatting these diseases and scab. It is probable that even where only one crop of potatoes is grown on the same land in five to six years the result is merely greatly to decrease the number of organisms in the soil without actually annihilating them. The next season after potatoes, the soil prob-

ably teems with the disease organism, but each year thereafter they get fewer and fewer until in five or six years they are at a low enough ebb to make another crop safe even in an unfavorable season. Some workers think that virgin soils carry *Rhizoctonia* organisms. If so they are not in numbers great enough to destroy the first crop of potatoes.

Seed selection must also be practiced to avoid the planting of infested seed. *Fusarium* can be detected by cutting a thin slice ($\frac{1}{8}$ inch thick) from the stem end. Any tubers showing brown or dark spots should not be used for seed. Badly scabbed tubers should also be discarded, as should tubers with many specks of *Rhizoctonia*, especially if these specks are larger than a half wheat kernel. Leniency with disease in choosing potatoes for seed is likely to be as short-sighted as half-heartedness in quarantining against small-pox or scarlet fever. The pulling out and burning of diseased plants may help in disease control.

Treatment with chemicals, if wisely used, may be of considerable assistance in controlling disease. Either of two treatments may be used: (1) corrosive sublimate, or (2) formalin. Seed potatoes should be treated before they have started to sprout. Sometimes vitality is decreased when treatment is applied after growth is well begun.

Corrosive sublimate is more effective but is considerably more expensive than formalin. Four ounces of the sublimate powder (HgCl_2) is dissolved in thirty gallons of water. *After being selected*, but before being cut into sets, the tubers should be soaked for $1\frac{1}{2}$ hours in the solution. Because it corrodes metal, wooden vessels must be used for this treatment. The solution becomes weaker during treatment by part of the sublimate's uniting with the protein of the potato. Not more than four lots of potatoes should be treated in the same solution. Sacks should not be immersed because they absorb great quantities of the sublimate thereby decreasing its strength still more rapidly.

Caution:—Corrosive sublimate is *deadly poison to man and beast*. Discarded solutions are best poured in holes and covered with at least two feet of earth. It is not injurious to the hands unless open wounds are brought in contact with it.

The formalin treatment is administered in the same way except that wooden vessels are not required. The solution is made by adding a pint of commercial formalin (40 per cent) to thirty gallons of water. Old formalin loses strength if left exposed to the atmosphere; hence sealed cans are safest. If they cannot be obtained inquiry should be made as to freshness and strength. The potatoes should be allowed to soak two hours. Any number

of lots of potatoes may be treated without impairing its strength. Animals or persons will be sick if they drink the solution, but it is not deadly like corrosive sublimate.

Thrifty growth greatly helps potato plants in overcoming weak attacks of these diseases. On this account every precaution should be taken to promote vigorous growth. Good seedbeds, moderate irrigation, and timely, clean cultivation encourages rapid, healthful growth. The effects of early blight, tipburn, and mosaic are largely offset by such favorable conditions. Spraying the vines is practiced in the East and Middlewest for early blight, tipburn, and late blight (the worst of all potato diseases, but one that has not yet caused trouble in the arid West) but these diseases are not yet serious enough in Utah to warrant spraying.

SEED CONSIDERATIONS

Seed potatoes in particular should have been stored in a cool, well-ventilated storage place. This maintains the vitality of the buds and preserves all the starch in the tuber to feed the young plant until it can establish itself in the soil.

Tuber selection of some sort is essential in choosing tubers for seed. Selection by the hill method the previous autumn is best. Lacking this, the grower will find it profitable to select from his cellar bin. Because of hereditary characters good marketable tubers are safest. The tendency to use culls for seed because they are unmarketable is bad practice, since most of the culls come from poor hills. Gilmore* reports that in a crop having 18 per cent culls, 76 per cent of these came from weak or unproductive hills. It seems only reasonable that the use of rough or otherwise undesirable tubers for seed is apt to produce a higher percentage of potatoes poor in the same respect than is the use of good tubers. The practice of choosing for seed the poorest hills plus a few of the poorest potatoes from the good hills appears to be little short of folly. The poorest-trained animal breeder in the country would not consider for a moment the selection of the poorest animals for parent stock.

Sprouting is a new but growing practice. With the seed selected according to the best method in keeping with his circumstances and with tubers selected against disease and properly treated, the farmer may find it wise to prepare for cutting by sprouting, or "greening" his seed. This consists in exposing the potatoes to diffuse light for two or three weeks, after treating chemically, but before cutting. Short, green, tough shoots begin growth. These do not get long as do those sprouts which develop in dark storage places that are too warm.

*California State Circular 161, p. 2.

Sprouting in the dark is detrimental because the sprouts must be broken off, thereby causing extra labor besides depleting the tuber of just so much food for the plant when it does begin growth. The short, green sprouts, however, are not broken off. Growth following such treatment begins much sooner especially if the ground is somewhat too cool or too wet at planting time. Sprouting enables the grower to detect and discard tubers with dormant buds and with concealed interior rot. Better stands and consequently higher yields may therefore be expected.

The size of seed piece for planting has received attention in all parts of the country. Some farmers prefer whole tubers for seed, others half tubers, and still others cut pieces—"sets" they are called—varying in size from one-half ounce to several ounces. A few growers plant a crop late in the season so as to have small, immature, whole seed for the next season's planting. Usually, however, cut pieces are used. Blocky sets from one to two ounces in size with one or two vigorous eyes in each set seem to be best. Tables III and IV, showing results from Canada and from Idaho, indicate that one to two ounce seed pieces produce greater net yields of marketable potatoes than either larger or smaller pieces.

Table III. The Influence of Size of Potato Set on Yield in Ontario.*

Size of set (oz.)	No. eyes in each set	Seed to acre (bushels)	Per cent marketable	Marketable (bushels)	Total (bushels)	Total less seed (bushels)	Marketable, less seed (bushels)
1/16	1	1.3	61.0	36.8	47.5	46.2	35.5
1/8	1	2.6	88.6	78.8	89.7	87.1	76.2
1/4	1	5.2	89.7	98.4	111.1	105.9	93.2
1/2	1	10.3	88.7	109.4	129.0	118.7	99.1
1	1	20.6	89.5	129.9	148.4	127.8	109.3
2	1	41.2	87.6	149.7	173.9	132.7	108.5

In table III Zavitz reports tests on sets 1/16, 1/8, 1/4, 1/2, 1, and 2 ounces in size. Total, marketable, and net yields increased with the size of seed up to one ounce which yields practically the same as two-ounce sets. In table IV are given results and computations from results obtained by Aicher at Aberdeen, Idaho. His results show an increase in total yield from the largest sets, but the quantity of seed used is so large and the percentage of culls is so high for the large pieces and for the whole tubers that one-ounce sets gave the highest net yields, that is, the marketable yield minus the seed used. Culls, however, are worth something. The assumption that they are worth one

*Ontario Sta. Bulletin 238, p. 43.

fourth as much as salable potatoes does not influence size of set that gave the highest net yield.

Taable IV. The Stand and Yield from Planting Whole, Halves, and Quarters of Potato Tubers which Weighed 8, 4, and 3 ounces. (1913-1916) (Idaho).*

Size of tuber and Set	Stand, per cent.	Stalks to the Hill	Per cent marketable	Acre-Yield					
				Total (bushels)	Marketable (bushels)	Culls (bushels)	Seed planted (bushels)	Net—marketable less seed (bushels)	Net plus ¼ culls (bushels)
8-oz. whole.....	99.97	8.67	52.6	392.9	200.6	192.3	96	104.6	152.7
8-oz. halved.....	99.97	4.71	65.2	333.5	210.5	123.0	48	162.5	193.2
8-oz. quartered..	89.28	2.63	69.1	314.0	218.2	95.8	24	194.2	218.2
4-oz. whole.....	99.99	5.41	46.3	368.7	171.0	197.7	48	123.0	172.4
4-oz. halved.....	99.99	2.98	66.1	332.9	220.1	112.8	24	196.1	224.3
4-oz. quartered...	89.31	1.71	77.4	322.7	250.9	71.8	12	238.9	256.9
3-oz. whole.....	100.00	4.82	54.2	361.7	201.1	160.6	36	165.1	205.3
3-oz. halved.....	98.87	2.64	68.8	355.5	253.8	101.7	18	235.8	261.2
3-oz. quartered...	82.19	1.72	78.0	262.7	201.5	61.2	9	192.5	207.8

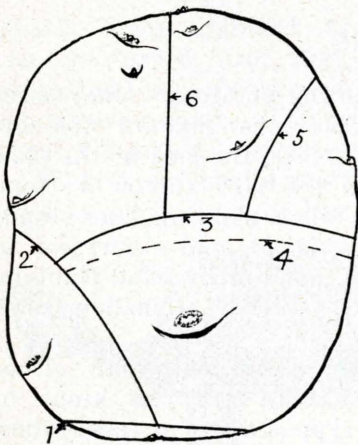


Fig. 6.—Diagram showing order of cuts in cutting potato sets for seed. The first cut (1) is a thin slice to show whether there is any *Fusarium*. Cut No. 4 is behind.

Cutting is best accomplished by hand. Machines cannot look for eyes and must be fed by hand. A stationary knife is much used in Colorado and other regions. It is somewhat faster and nearly as accurate as hand cutting. The operation of cutting is best begun at the stem end, the end having the fewest eyes. If a thin slice was taken off the stem end before treating, it should be done now and all tubers showing brown spots discarded. The knife used for cutting should be immersed in formalin for a few minutes after cutting an infested tuber. This necessitates the use of two or three knives for each cutter. Such practice is not

a drawback, since the knives will keep sharper and thereby cause less weariness of fingers and wrists.

After the thin slice is removed from the stem end of the tuber, the first set should also be taken from that end in such a way as to make a piece about the size of a hen's egg with one or two strong eyes in it. The succeeding sets should be cut after the same fashion until only enough tuber is left for two sets. The piece should then be split in such a way as to divide the cluster of eyes at the bud end of the tuber. This avoids getting so many eyes in one set as to produce several shoots and consequently a high percentage of small potatoes.

Cutting is best done on the same day as planting. Where this is impractical, it should not be more than one day before. This decreases danger of mould or of the drying out of the sets. Sacks in which sets are placed should be piled so as to permit thoro ventilation. These sacks should have been soaked in formalin to sterilize them. Corrosive sublimate is so deadly as to be dangerous for treating sacks. The sacks should, of course, be dried before being filled with sets.

Some growers sprinkle the cut sets with road dust, slaked lime, or powdered gypsum before planting. This, they think, helps to dry out the surface and therefore, prevents evaporation. Dusting is not practiced unless planting is not to take place for sometime after cutting.

PLANTING

There are several methods of planting potatoes. Many acres are planted behind the plow that turns under manure; the sets are not always thrust into the loose soil on the side of the plow furrow but are too often dropped on the hard furrow bottom. This is risky, for should a dry period follow planting, poor stands are likely. Another and better way is to make furrows in prepared soil, to drop the potatoes by hand or by hand-planters, and then to cover them by dragging, or with a shallow plow furrow.

Machine planting, however, is more efficient than either plowing in or planting in furrows. There are two kinds of machine planters in use, the picker type and the notched-wheel type. The picker takes the sets out of a hopper by means of spikes which are fastened to a revolving vertical disk and drops them down a pipe into the furrow. The other machine does the work by elevating the sets to a notched, revolving, horizontal disk which is watched by a man, who fills empty notches or removes a set if two get into one slot. When the notch passes over the delivery spout, the set drops thru. The picker machine

requires only one operator, but misses from 5 to 20 per cent of the time, with an average failure of 15 per cent. The notched-wheel planter requires two men but can be made to miss less than 1 per cent of the hills. The picker machine may transfer

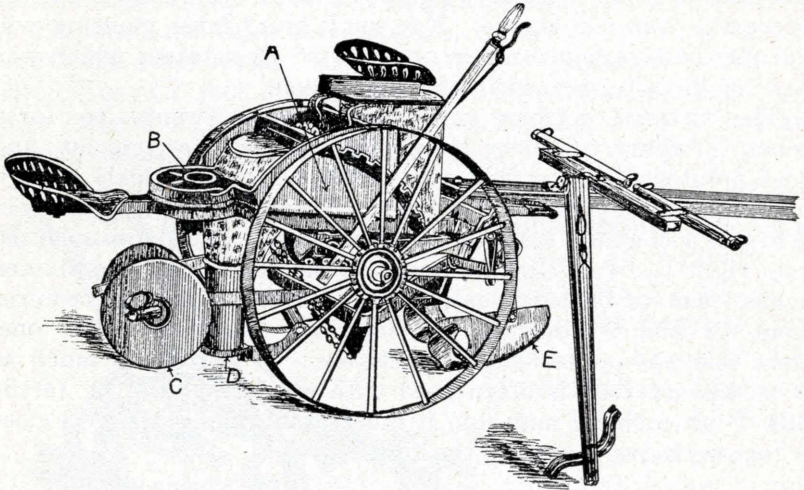


Fig. 7.—Notched-platform potato planter. A, hopper carrying cut sets; B, notched platform; E, furrow opener; D, drop spout; C, covering disks. Two operators can plant nearly all the hills—about 95 per cent efficient.

disease from infested to healthful sets. The horse-power planters furrow, drop, and cover five or six acres a day. It is estimated that a farmer can afford a machine planter if he grows six acres or more. The picker type of planter normally costs about \$70 and the notched-wheel type \$85, or thereabouts.

There is no fixed depth for planting. From two to six inches is usual, while three to four is most common. Light, warm soils permit planting to the depth of five or six inches. Heavy soils require planting as shallow as possible without endangering the growing tubers of exposure to the light, which injures them by causing chlorophyll to develop. In sands four to six inches is better because it protects the tubers from excessive heat at the surface.

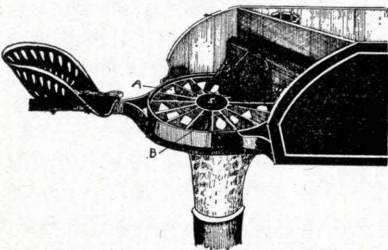


Fig. 8.—The notched platform. A, set in slot; B, empty slot. Operator sitting behind platform fills empty slots.

Early potatoes are planted as soon as the soil becomes reasonably warm, and late ones usually in May, tho in some

districts, early June is the best time. Planting as late as safety warrants that they will mature has given the best potato yields where water is abundant. Where water is scarce early planting is usually counted more satisfactory so as to secure most growth before the water shortage. For small areas later planting will probably be best, since water can be used on potatoes which was used for hay or grain earlier in the season.

The distance between rows varies from twenty to forty inches. Twenty to thirty inches may be best for garden and truck potatoes, but the field crop should be spaced widely enough to permit horse-power cultivation. Twenty-eight to thirty-six inches is a common distance between rows. Sets are planted from eight to twenty inches apart in the row; twelve to sixteen inches seem to be most satisfactory. Such planting requires about 12 and 24 bushels an acre for planting with one-ounce and two-ounce sets, respectively. In Europe as much as 40 bushels of seed is often used with good results. On fertile soils, Utah farmers may find it more profitable to plant as close as ten or twelve inches in the row.

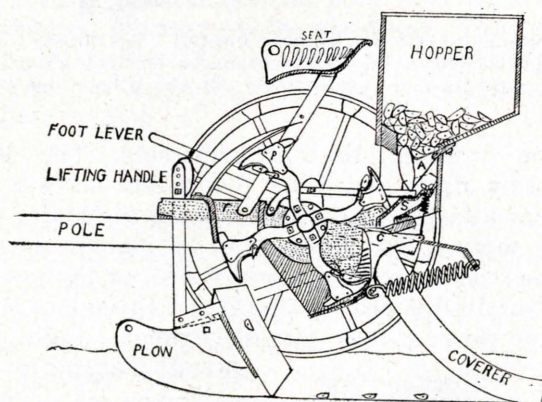


Fig. 9.—Diagram of picker type of potato planter. P, picker arm; A, opening from hopper; S, spout to C where spring pushes set against spike on picker arm. Operated by one man but plants only 85 per cent of the hills.

CULTIVATION

While the seedbed is being prepared is the most effectual time to cultivate potatoes. Fine, mellow seedbeds with the under soil well firmed and the surface well mulched demand but little subsequent tillage unless the land is somewhat foul with weeds or has a strong tendency to bake. Potatoes on good seedbeds will demand only two or three harrowings and two or three cultivations.

Harrowing is most advantageous just before the potato plants begin to show above ground. A spike-tooth harrow with the teeth set well back will break any crust that may have formed and scratch out any weed seedlings that may have germinated. If the plants are beginning to show, it may be wise to harrow across the rows rather than with them in order to avoid the possibility of a root or a piece of undecayed manure that might have caught on a harrow tooth from running down a row and tearing out several plants in succession.

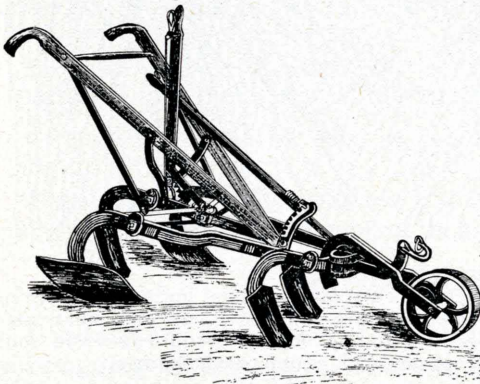


Fig. 10.—A one-horse, one-row cultivator.

Where areas of any considerable size are grown, all cultivation or very nearly all of it should be done by horse power. Probably the most available implement now in Utah is the ordinary one-horse five-tooth cultivator. Most farms are already equipped with one of these. It is effective but can be made to cultivate only

one row at once. The operator's time is not used nearly efficiently as it is with two-row or four-row cultivators such as are used for beets or for corn in the Middlewest. Beet cultivators may be used, but they need a great deal more attention to avoid injuring the plants than do corn cultivators.

Soil can be cultivated close up to the plants if the land is not cloddy or filled with undecayed rubbish and if the rows are straight. As soon as the potatoes are up far enough to permit the rows' being easily seen it is time for the first cultivation; or a good harrowing if preferred. The first cultivation should be close up to plants and shallow near the row but considerably deeper near the middle where the irrigation furrow is to be made later. This dries out the top soil and encourages the roots to develop below the stirred soil. It is well therefore in the first cultivation to move all soil that is to be moved at any other cultivation or in the making of the furrow for irrigation. This helps to prevent roots from developing where they will be injured. No furrow, however, should be made at this cultivation. Potatoes naturally root near the surface unless this precaution is taken early in the season. The cutting of many roots when the furrows

are made is almost sure to weaken the plant and to delay its growth just when it should be most vigorous.

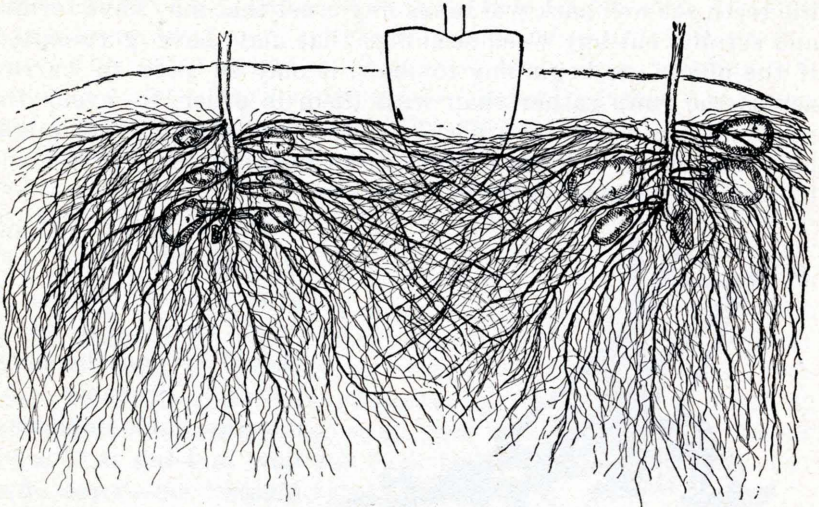


Fig. 11.—Diagram showing how cultivator shovel cuts roots when irrigation furrows are made if the roots are allowed to develop near surface. Early deep cultivation dries out the soil between the rows and causes the roots to develop deep enough to avoid being injured.

The second cultivation will ordinarily come between two and four weeks later, that is, about the time the potatoes begin to show need of water. At this cultivation the irrigation furrows may be made and the soil stirred as close up to the plants as possible without allowing the side teeth to break off roots or tear out plants. There is no advantage in deeper furrows or in higher hilling than is necessary to carry the water and to protect the potatoes from sunlight. Excessive hilling exposes the soil to hot sun and to high evaporation. If there are many weeds showing in the rows it may be wise to pull these by hand or to chop them out with a hoe. On the other hand if there are but few weeds, it is not likely to pay to weed at a special operation, since a few scattering weeds may be pulled out during irrigation by the man tending the water, especially if he is using only a small stream and the land is well laid off for irrigation.

Within a few days following the first irrigation a crust will have formed on most soils and many weeds will have germinated. This is the opportune time for the second or third cultivation as the case may be because the weeds are most easily killed while they are small and because any crust formed is broken before too much evaporation has taken place. The third cultivation should follow the second irrigation in the same way. This will be the last cultivation necessary, provided of course, the land was not

foul with weeds or there has been no neglect in the preparation of the seedbed. In case of weedy land another cultivation and one or two thoro hand weedings may be required. Soon after the third cultivation the potatoes will begin to spread across the row. It is then too late to cultivate with horse-power machinery for the vines will be broken or trodden on.

All experiment stations where potatoes are a common crop advocate that cultivation be avoided while the plants are wet. There are two reasons for this. The first is that the stems and leaves are then more brittle on account of the turgidity due to an abundance of water in the cells of the plant. The second reason is that certain diseases are more readily spread by cultivation when small droplets of water are hanging on the leaves.

INSECTS

Many insects attack potatoes but none have as yet made it necessary to adopt special control measures in Utah.

IRRIGATION

Potatoes are sensitive in their moisture requirements. Tho waterlogging is disastrous, extreme drouth is not favorable. Some varieties withstand drouth but yields are usually low under such conditions. Nearly every person who has had much to do with potatoes advocates that they be irrigated only moderately heavily. The deep loams and clay soils which compose nearly all the best farming lands of Utah probably require only three or four irrigations. Porous sands and gravels will require four or five lighter applications. The low water-holding capacity of these soils makes it imperative to apply water more frequently but in smaller quantities. From 15 to 20 inches is probably the right amount to apply during a season in most sections of Utah. Very gravelly soils may require more than five applications but if so, the applications should be still smaller, and applied rapidly to insure uniform distribution.

The first application should come neither too early nor too late. It is too early if the plants will not suffer for some time and if irrigation will cool the ground excessively. It is well, however, to apply water before the plants wilt so badly that they take on a dark unhealthy color and stop rapid growth. Farmers of some sections can get water whenever they wish it. These men will do well to irrigate potatoes as soon as the vines begin to take on a dark color and show signs of being wilted at other times than in the middle of the day.

Where the water goes from one farmer to the next in "turns"

it is well to irrigate soon enough. Unless the season is a cold one, it is probably safer to irrigate a few days too early rather than a few days too late as the missing of a turn might necessitate. It may be wise, on porous soils, to irrigate every alternate row one turn and the other alternate rows or all of them the next turn, giving just enough the first time to make sure that there will be no retardation of growth. Both of the applications taken together would be counted as one complete irrigation. If the irrigation stream is rapidly decreasing in volume it may be wisdom to irrigate rather early, especially if the season is warm. The main thing to be accomplished is to avoid a retardation of growth due to a lack of moisture since this may materially decrease the yield.

Considerable care should be exercised to get enough water to the plants at the lower end of the rows without over-irrigating those at the upper end. This is best brought about by running the rows in such a direction that there is enough slope for the water to run readily but not enough to cause much washing. A good head of water should be used and the head-ditches should be near enough to permit the water to run quickly to the bottom of the rows. On coarse sands, sandy loams, or otherwise porous soils, this is especially important. It is easy to run small streams down long furrows and shut them off as soon as the water reaches the lower end. This, however, distributes the water very unevenly, because the top is thoroly soaked—often wastefully so—before the lower end is scarcely more than wet in the furrow bottoms. It is good practice to start at one end of the field and work to the other, allowing the water that has passed thru the furrows of one “run” to pass into a few furrows on the one just below. This avoids wasting water.

In case the land is uneven, somewhat steep, or difficult for some reason, it is often advisable to provide sod, or coarse manure if sod is unavailable, for helping to regulate the water in the furrows. A load of sod scattered along the head ditches before irrigation is begun may save time and trouble. Small inlets for each eight to twelve furrows are of great assistance for controlling water on uneven or steep land. Sometimes it is also advisable to have a number of sharpened willows or pegs to help hold sod or weeds for turning a part of the stream into one of these inlets. Canvas dams are also convenient.

The time for the second irrigation will be somewhere near blooming time. The furrows have been stirred with the cultivator after the first irrigation, but the “regulation” of the furrows in the small inlet ditches should not have been disturbed, unless it is advisable to run water twice as far the second time.

In this case every alternate head-ditch is cultivated across and the furrows made continuous. When the vines get long, however, they hang into the furrows and render it difficult to run the water long distances. It may therefore be best to use short "runs" thruout the season. The last irrigation—whether the third or sixth—should not be delayed late enough to prolong the growing season so late in the fall as to make harvest in damp soil necessary. It is commonly accepted in Utah, California, Colorado, and other western states that no water should be added later than about a month before harvest. Wet soil makes digging difficult and leaves the potatoes dirty. Extremely porous soils may be irrigated at almost any time, but most of our land falls in the class which needs attention in this respect.

The Utah Experiment Station tested the irrigation of potatoes for five years. Some plats were irrigated each week and others at different periods in the growth of the crop.

Many towns irrigate their city lots each week. For these the weekly applications may be taken as typical. Water applied at the rate of 1, 2½, 5, and 7½ inches weekly to different plats, making totals for the season of 12.8, 32, 64, and 96 inches, gave yields of 337.1, 300.9, 190.9, and 140.5 bushels, respectively. The plat that received no irrigation at all yielded 153.3 bushels. The light weekly application was best and the very heavy poorest, poorer even than land receiving no irrigation. There were also less marketable potatoes for the heavier applications.

The other phase of the test applies to the field culture of potatoes where water can be had as desired. Four stages were arbitrarily chosen: (1) when the vines were four inches high, (2) when tubers began to form, (3) when plants were in full bloom, and (4) when the tubers were ripening. Another plat was irrigated after planting but before the plants showed above ground.

The irrigations were applications of five inches each. Four plats were irrigated only once; others received two irrigations of five inches each in different combinations of stages; others three; and one four, that is, in all four stages. The plat receiving a five-inch irrigation in each stage and one receiving it in the last three stages outyielded the others.

The yield with no irrigation was 153.3 bushels; for one five-inch application the results were: after planting but before coming up 139.0 bushels, first stage 193.9 bushels, second 201.4 bushels, third 229.0 bushels, and fourth 180.1 bushels. Omission of first stage when three applications were made gave 294.8 bushels, omission of the second 257.2 bushels, of the third 256.4 bushels, and of the fourth 246.4 bushels as against

317.1 bushels for applications in all four stages, and 153.3 bushels for none. The high yield of the non-irrigated plat shows that abundant water was stored in the seedbed. These results are what might be expected on well-prepared soil of the same kind—a deep, fertile clay loam. The later irrigations seem more important on this account. Applications in the last three stages with the first omitted gave nearly as high yields as did irrigation in all four stages. A dry season or a poorly prepared seedbed would probably have shown greater value for the first application.

From the above it is clear that light weekly irrigations are best for small areas, where the water passes around in weekly turns. One inch of water is just enough to wet the soil for a few inches at the surface. Under field conditions such frequent and such light applications would cost too much, and would also cause too many weeds. Three or four heavy irrigations seem to be better under such conditions on loams or clay loams. Five inches in one application is a thoro irrigation but one not heavy enough to swamp the land. Because sands, gravels, and sandy or gravelly loams will not be able to retain five inches, five or six **lighter irrigations** applied oftener will probably give better results.

Some growers maintain that it is bad practice to irrigate potatoes at blooming time. There is no available experimental evidence bearing out this conclusion. Utah Station results seem to indicate that the period of full bloom is one of the best times to irrigate. This was the third stage in the experiment cited. Results for application in one stage and for the omission of one stage show the second and third stages to be the critical ones with the third possibly more critical than the second.

After all, however, irrigation may be summarized in the one statement that the ground should be kept moist enough thruout the growing season to permit continuous growth. If the ground dries sufficiently to check growth, there is danger that the tubers will become knobby or gnarled. Sometimes an eye from the bud end sprouts and one or several small tubbers are formed at the expense of the original tuber. Such "second growth" is disastrous for it makes the first tuber soft and soggy as well as causing a high percentage of small, immature tubers.

IMPROVING THE CROP

Considerable improvement in the yield of potatoes may be expected by practicing thoro tillage, intelligent irrigation, and disease control. Hill selection is another efficient means to the same end. This consists of choosing for seed those hills that

produce a high yield of desirable tubers. If a hill produced other hills exactly like itself year after year, the original selection would be all that was necessary to improve yields. Some plants, however, may themselves be good producers but lack the power to transmit this quality in the next generation. Three or four years are necessary to find out whether the hills selected for seed will produce true to type. The method, however, is so simple as to require but little time or training. The doing of it is what counts.

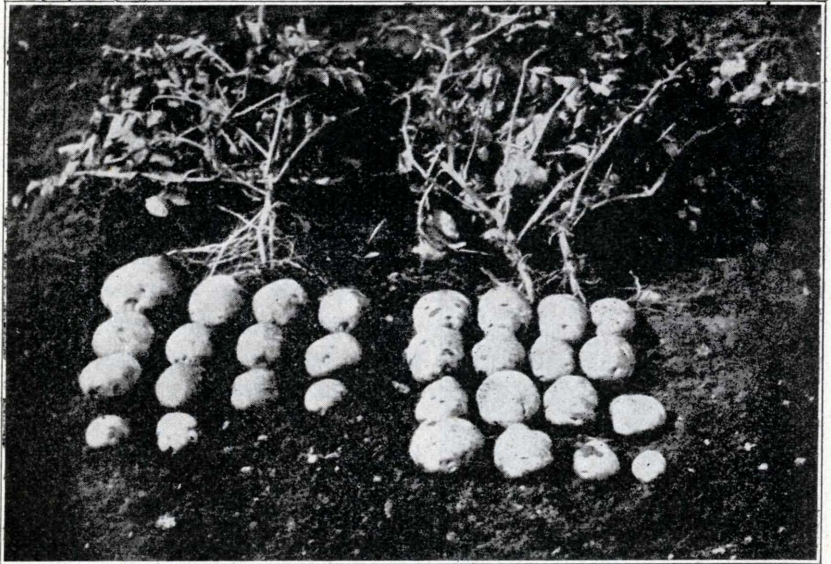


Fig. 12.—Two selected hills. Note the great number of uniform potatoes in each. (Courtesy Dr. George R. Hill, Jr.)

Probably the best time to begin selection is rather early in the summer, about the time the vines have reached full size. A large number of small pegs long enough to show above the vines may be used to mark the most promising plants. The whole field should be looked over carefully to find that part of the field where the stand is most uniform. Then those vines which look thriftiest and yet have no advantage in extra space, better soil, or more moisture should be "pegged." It may be wise to mark at least double as many hills as the grower wishes to select; four or five times as many will be better.

The time between pegging and harvest gives opportunity for frequent observation of the marked vines. Many of them will fail to maintain the vigor for which they were chosen. The stakes

should be removed from these. Just before the general harvest, the farmer should dig the marked hills with a digging fork, leaving each hill by itself. Many of these will be disappointing, but some—perhaps half—will be reasonably high-yielding hills of good-shaped, medium-sized potatoes. If two hundred hills are dug but only a hundred selections desired it may be wise to place these reasonably near each other, and discard the poorest repeatedly until the number of hills is reduced to the number desired. The selected tubers may be mixed into sacks or crates and carefully stored till spring. The more interested farmers will find it profitable to sack each hill separately before storage.

In case no pegs were used during the summer the farmer merely chooses that part of the field that was healthiest and had the evenest stand. He should dig several times more hills than he expects to select, saving only the very best ones.

A seed plat is profitable on every farm growing one acre or more of potatoes. This plat is merely a marked part of his field in which are planted the tubers selected the previous autumn. The hills selected should be treated for disease and cut exactly as is the field crop. Let the sets from each hill be kept separate and planted; then a stake should be driven in firmly enough to remain till harvest. If this peg is placed in the row, cultivators or irrigation need not disturb it. The sets from the next hill is then planted and another stake set until all the

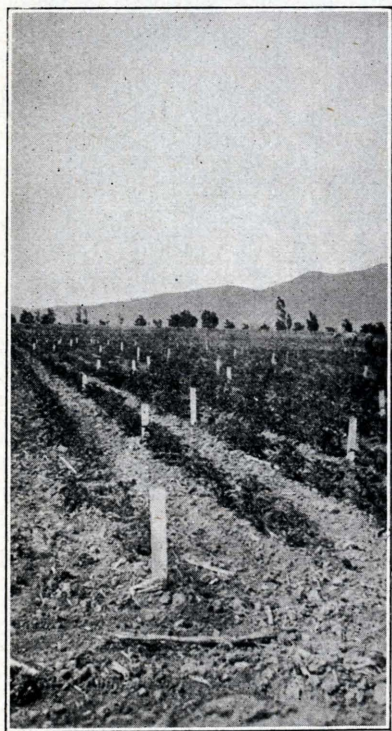


Fig. 13.—Potato-breeding plat, Utah Experiment Station.

selections are planted and staked. These will be watched thruout the season and at harvest time all dug by hand—on the same day if possible. When all the hills are dug, the rows should be examined and judged against each other. The unusually poor ones may be discarded entirely as being no better than the ordinary crop. If two or three rows are flatteringly high yielders

all the hills of these rows should be saved for a seed plat next year. The year following, this seed plat will grow enough to plant an appreciable part of the general crop. Large growers will find it highly profitable to maintain a selection plat, a test plat, and a multiplication plat every year. Smaller growers will use only one seed plat.

In case no row shows markedly high yields the year following the initial selection, the grower should select the better hills from several of the best rows for a similar plat next year. This should also be done in case a few rows are decidedly high yielders. It is also well to dig from the ordinary crop each fall and to select a few promising hills to add to the selection plat. In a few years considerable improvement can be made in total yield and in the percentage of marketable tubers.

Ontario experimenters selected eleven strains and tested these for three years, after which time acre-yields of 243.4 bushels, 216.3 bushels, and 190.8 bushels were obtained from the best three strains. The average acre-yield in Ontario is about 120 bushels. Colorado growers have also made considerable gains in the same way.

The Utah Station has selected potatoes in this way since 1912. The results are shown to be even more marked than those of Ontario. Table VI gives a brief summary of these results.

Table V. Acre-yields and the gain over unselected strain of seven selected strains at the Utah Experiment Station.

Strain	Years selected	Acre-yield (bushels)	Gain over Unselected	
			Acre-yield (bushels)	Per cent
Unselected	0	158.8	0	0
General*	3	188.7	29.9	18.8
Mixed†	5	173.7	14.9	9.4
1—6	7	178.4	19.6	12.3
3—13	7	226.8	68.0	42.8
3—15	7	282.4	123.6	77.8
3—19	7	246.5	87.7	55.2
5—7	7	194.8	36.0	22.7

*All good hills from breeding plat except a few of the best selected for breeding.

†The remnant hills of two good strains after about half of each were selected for breeding plat.

HARVESTING

Except for a few in home gardens, early potatoes are mostly grown in the trucking sections and are usually harvested before maturity for sale on high-priced city markets. The potatoes are small and must therefore bring considerably higher prices than

potatoes dug nearer maturity. Kohler* at Minnesota made a study of yield at various times of digging with the results shown in table VI. Since Early Ohio potatoes were used in the experiment, it is somewhat representative of our conditions.

Table VI. The yield of Early Ohio Potatoes Dug at Different Dates. (Minnesota, 1910).

Date of Digging	Acre-yield		Daily Gain Marketable (bushels)	Per cent of vines dead
	Total (bushels)	(bushels) Marketable		
July 31.....	38.7	10.9		0
August 7.....	87.7	62.3	7.5	1
August 14.....	141.5	115.4	7.6	8
August 23.....	203.2	182.1	7.2	22
August 30.....	253.8	226.8	6.4	99

*Minn. Sta. Bul. 118, p. 109.

From this it can be seen that if only the potatoes are considered it is rather doubtful whether early digging is profitable. The yield was somewhat more than six times as great Aug. 30 as it was July 31. The marketable yield is 20 times as great. Calculations from this table show that with even one or two weeks earlier digging much higher prices must be received. If the price at complete maturity is to be 75 cents a bushel, the grower must receive \$1.29 two weeks earlier and somewhere near \$5.00 four weeks before maturity. Too frequently this difference is not obtained, but the farmer is safe because he usually uses the land for a late short-season crop such as cabbage, cauliflower, or beans.

The late crop is usually allowed to grow until all the vines are dead or until danger from frost becomes imminent. This is usually late in September or October. Late irrigation should be avoided on heavy soils in order to encourage maturity and to prevent too much dirt's sticking to the potatoes.

Many small fields are dug by hand with a potato fork or hook. This is hard work and rather slow, but may be cheaper for small areas than the use of horse power. If seed is to be saved from a hand-dug field, the digger should be constantly alert for high-yielding hills to supplement his selection plat.

For digging the larger fields, ordinary stubble or shovel plows are used too generally. They cover or cut too many potatoes to make them desirable implements. Where the area of potatoes grown is too small to justify a digger and where the plow is used, it requires considerable care to gather the large number of potatoes covered by the plowing. Volunteer plants are a nuisance to the next crop, besides carrying over diseases. Small walking diggers are much better than plows and can be obtained at small

outlay, especially if three or four farmers buy one coöperatively. It is likely, however, that two acres will pay for a small digger in one season, since they cost only about \$20 a piece.

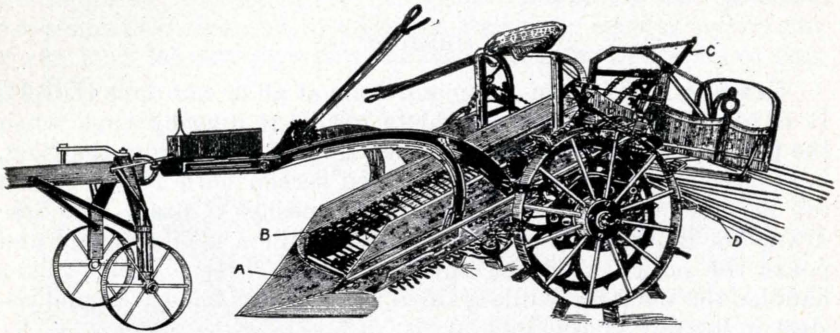


Fig. 14.—Diagram of elevator potato digger. A, blade which passes under hills; B, elevator rods; C, spring release for throwing off vines; D, device for separating very small and very large tubers from medium-sized ones.

In sections that grow considerable areas for market most growers are using the elevator digger, or should be. The blade of the digger passes under the hills, and the elevator carries them up and shakes off the dirt. Some have grading attachments on them, but another machine is usually used for this operation. The large diggers cost from \$80 to \$150 and require four horses for efficient draft. In some sections, many potatoes are injured by setting the blade of the digger too near the surface. It would pay to use another horse and set the blade below the hills. Three to five acres can be harvested in a day with one digger and an efficient crew. Compact soils increase the draft tremendously; here is another good reason for more careful plowing, manuring, and irrigation.

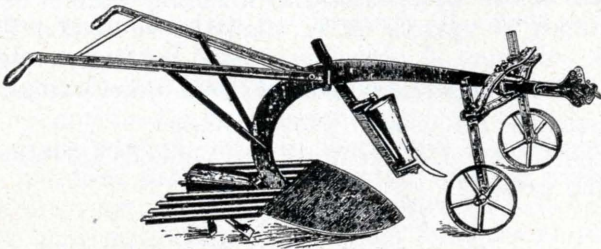


Fig. 15.—Small digger. Much better than plow. Bars at back are jerked up and down by arms beneath.

Picking is frequently done immediately behind the digger. It is usually wise for the potatoes to lie on the ground for about an hour. This allows dirt to dry and moisture from the skin to

evaporate before grading and sacking. Dirt rattles off in handling, and fewer potatoes spoil in storage or shipment due to moisture which favors rotting. It is likely that there will be less bruising with dry tubers.

GRADING

Grading is too often either not done at all or not done thoroly. It is probably more economical to grade at digging time when the potatoes are to be stored. When they are sold from the field, it is necessarily done then. A mounted screen with 1½ to 2-inch top meshes and ¾ to 1¼-inch bottom meshes is used. A horse draws the machine from place to place while a man picks up and pours the potatoes on the apron of the screen. The driver handles the machine while a third sews or ties the sacks and assists in loading or nicking.

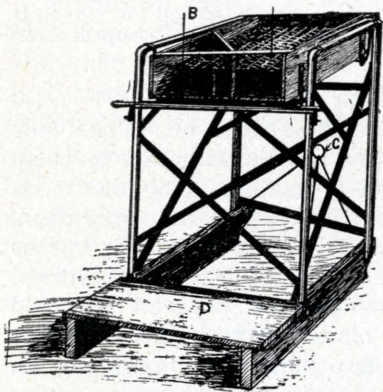


Fig. 16.—Hand grader and sorter. A, screen over which marketable tubers pass; B, exit for small tubers that pass thru screen A; C, device for hooking to horse; D, platform for sack.

Too little good grading is done for the benefit of the farmer. He usually gets less for his ungraded crop and besides loses the culls for feed. Some sections have fallen into the bad practice of leaving culls in the field. If hogs or sheep pasture the fields most of these will be gathered if snow does not cover them, or frost ruin their feeding value. It would pay handsomely to pick up, store, and feed them. Moreover, the next crop on the land would not be troubled with volunteer potatoes as weeds. Rotations might also

be a year shorter under a system of clean harvesting because volunteer potatoes are usually badly diseased.

The Department of Agriculture recommends the adoption of the following grades:

U. S. Grade No. 1

“This grade shall consist of sound potatoes of similar varietal characteristics, which are practically free from dirt or other foreign matter, frost injury, sunburn, second growth, cuts, scab, blight, dry rot and damage caused by disease, insects, or mechanical means. The minimum diameter of potatoes of the round varieties shall be one and seven-eighths (1⅞) inches, and of

potatoes of the long varieties one and three-fourth ($1\frac{3}{4}$) inches. In order to allow for variations incident to commercial grading and handling, five per centum by weight of any lot may be under the prescribed size and in addition, three per centum by weight of any such lot may be below the remaining requirements of this grade."

U. S. Grade No. 2

"This grade shall consist of potatoes of similar varietal characteristics, which are practically free from frost injury and decay, and which are free from serious damage caused by dirt or other foreign matter, sunburn, second growth, cuts, scabs, blight, dry rot, or other disease, insects, or mechanical means. The minimum diameter shall be one and one-half ($1\frac{1}{2}$) inches. In order to allow for variations incident to commercial grading and handling five per centum by weight of any lot may be under the prescribed size, and, in addition, five per centum by weight

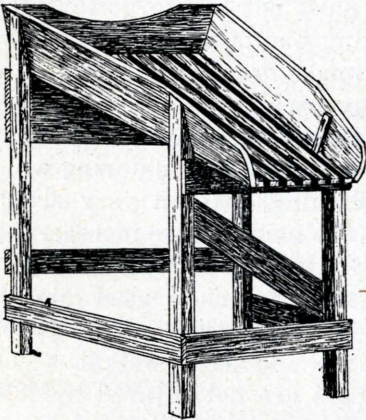


Fig. 17.—Simple device to assist in hand sorting.

of any such lot may be below the remaining requirements of this grade."

STORAGE

A good storage place for potatoes is one of the essentials to successful potato production. Some storage is required every season even when the commercial crop is marketed at harvest time. Seed stock for the next season's planting must be saved, and small quantities for home consumption are usually profitable. Many growers, perhaps most of them, find it profitable to store culls for livestock feeding. Since small space is usually ample for these purposes, it is only where appreciable quantities are stored for later marketing that storage facilities receive serious attention.

FACTORS IN STORAGE

The principles involved do not differ greatly whether a few bushels or several hundred are stored, or whether pits, cellars, or warehouses are used. Only the mechanism varies: the purposes to be accomplished and the end arrived at are identical.

The end aimed at is, of course, the maintenance of the potatoes in a firm, uninjured condition until the time of disposal. The factors that influence storage are temperature, aeration, size of the pile or bin of potatoes, light, humidity, and dry rot. To control each of these factors in the way or to the degree necessary for successful storage are the ends aimed at.

The best temperature for storage is somewhere between 36° F. and 40° F. This maintains the firmness of the tubers by re-

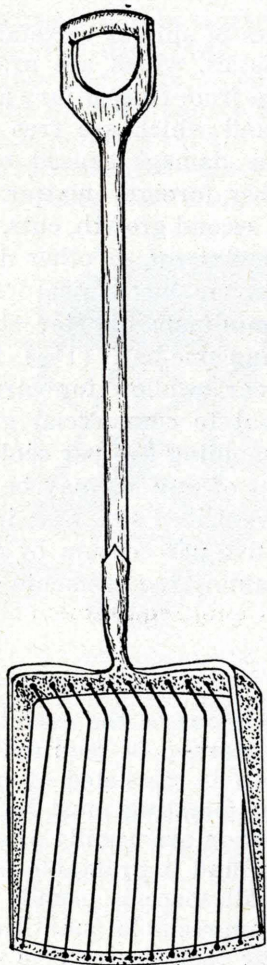


Fig. 18.—A good fork for handling potatoes. The plate in front of the tines prevents puncturing tubers.

ducing evaporation and the loss due to respiration to a minimum. It must not be forgotten that living plants as well as living animals breathe all the time they are alive. At a low temperature potatoes pass into a "rest" or dormant, period during which breathing goes on very slowly. As the temperature increases the rapidity of breathing greatly increases. Starch is used up by rapid respiration and the tubers soften and lose weight. The tubers are not injured by frost until a point three or four degrees below the freezing point of water is reached, but potatoes held for any great length of time near 32° F. acquire a sweet taste when cooked. At 36° F. and at higher temperature this sweet taste does not develop, because starch does not change to sugar in any quantity as it does at lower temperatures. Above 40° F., breathing is so active as to cause appreciable loss. Precautions must therefore be taken to reduce temperature, especially if the potatoes are stored during hot weather.

Aeration, or ventilation of the storage place is essential in order to carry off the water and carbon dioxide which are excreted in breathing. The air expired from an animal is laden

with water vapor and with foul gases, chiefly carbon dioxid. The products of plant respiration are the same. Dr. George R. Hill*, pathologist for the Utah Experiment Station, has shown that peaches and other living plant tissues become brown and lose firmness much more rapidly in an atmosphere rich in carbon dioxid than in normal air. This undoubtedly applies to potatoes in storage. Aeration is, therefore, essential.

The size of the pile or bin of potatoes is important chiefly as it has to do with aeration and temperature control. Sometimes when deep and wide piles are made the potatoes sweat, especially if they were somewhat immature at storage time. Considerable heat is given off and carbon dioxid is not removed. In extreme cases, the tubers take on a sort of cooked appearance and deteriorate rapidly into a soft pulp. Because of the bad effects of over-heating, piles should either be made smaller—4 to 6 feet deep—or provided with proper ventilation. A good way of doing this is to have a false floor in the bin and at intervals of 4 or 5 feet to make partition walls of 2 by 4 uprights with narrow boards fastened on either side in such a way as to leave a space of about an inch between. Some growers and wholesalers use crates, sacks, or barrels piled so as to secure aeration.

Light and humidity are of lesser importance, but still worthy of attention.

Sunlight injures potatoes that are to be used for food by causing them to develop chlorophyll and turn green. The chlorophyll greatly injures the cooking quality of the potato by causing it to become soggy and by giving it a bad taste. This is true whether the exposure takes place in the field or during storage. It is therefore best to have the storage place absolutely devoid of sunlight. Electricity should provide the necessary lighting.

The humidity is best when the air is of a medium degree of dampness. Extremely dry air, such as is likely to occur in the West, causes excessive evaporation. Cool closed cellars however soon acquire the proper degree of humidity. Excessive moisture causes a condensation of moisture on the tubers, which, unless removed, encourages heating and also the spread of storage diseases, such as dry rot, which is much the worst of our storage diseases. A soft, wet rot occurs but much less frequently. In California a disease called "leaks" causes trouble, particularly where the potatoes have been wounded or the knobs broken off. This disease causes water to be drawn from tubers sometimes rapidly enough to drain away from piles in streams.

Dry rot is caused by a *Fusarium* but by a different one from

*Cornell Expt. Sta. Bul. 330, p. 405.

that which causes the Fusarium wilt. Only cut, bruised, broken, or skinned potatoes are ordinarily attacked by this disease, tho in storage that is too warm and too humid, even the sound tubers may be injured. Control of temperature and aeration prevents the rapid spread of dry rot in bins. Cellars should be fumigated before putting each harvest in storage. The cellar is made airtight and fumigated by pouring one pint of liquid formalin over 23 ounces of potassium permanganate for each 1000 cubic feet of space.

Perhaps the best possible method of avoiding dry rot in storage is to discard in the field all injured tubers, storing only the sound ones. The keeping quality and the total market value of the crop will be increased by careful grading, in addition to which the discards can be fed to livestock.

STORAGE PLACES

Storage places on the farm are either pits or cellars in the West, tho in the South and in Maine especially constructed houses are used. However, in poorly drained areas where excavations cannot be made, adobe houses are frequently used to good advantage. In choosing a site for a cellar or pit it is highly important to have the ground well-drained. Because of this, side hills or knolls are frequently chosen.

Cellars are usually partly underground and partly above. If three or four feet of excavating is done, about enough dirt is secured to cover the roof. The potatoes are best unloaded by driving the wagon into the large cellars and by means of chutes into the smaller ones. Too many farm cellars are inconvenient for reception or for removal of potatoes. To carry the potatoes in sacks or in baskets down cellar steps and then out again at market time is too expensive in labor. Cellars should be provided with flues for ventilation and for control of the temperature. A top and a bottom flue are counted necessary, the intake being at the bottom. The use of false floors and double slatted partitions greatly facilitates ventilation. Storage in sacks or crates is also a great advantage. They are, however, so expensive as probably to make bulk storage inadvisable for the ordinary market crop. Selected seed is best kept in crates.

Pits, like cellars, should be built only on well-drained land. An excavation of six to twelve inches should be lined with straw and then filled with potatoes in the shape of an inverted V as high as they will stand without danger of tumbling down. A layer of straw that will be six or eight inches thick when compressed is placed over the potatoes and three or four inches of dirt scattered evenly over this. Flues at intervals of a few feet should extend to within about six inches of the floor of the pit.

"Monthly Crop Report" for October estimated the crop at 301 million bushels for the United States. As the season, however, had been decidedly unfavorable, the yields were injured more than had been suspected and only 285 millions were harvested. The normal consumption, which for the last twenty years has been nearly 3.5 bushels per capita, had to be largely curtailed. In other words, the demand exceeded the supply by about 100 million bushels. The price, which on November 1 was about \$1.25 a bushel, advanced steadily to \$3.00 a bushel or thereabouts at planting time. So great was the visible shortage that any person who had followed the crop reports could have predicted a marked advance in price.

The same is true for the 1917 crop, in that anybody could have predicted a "slump." The acreage had been increased materially due to the high price of the 1916 crop and due to the urging of the National Food Administration. This, coupled with the unusually high acre-yields due to an extremely favorable season, gave a decided over-production. Prices were reasonably good at harvest. Field men from the Bureau of Markets were urging farmers to "release" their potatoes, but the fabulous prices of 1916-17 had produced "itching palms." In the spring the market broke, completely overloaded. Prices dropped to 15 or 20 cents where buyers could be found. Thousands of bushels were left to rot in the pits or were carted off to garbage heaps.

Years either of unusually high or unusually low production permit almost certain prediction of the price. It is, however, but seldom that these unusual seasons occur. It is the nearly normal years that cause trouble. Taking the United States as a whole, it is safe to say that to store year after year is not a safe practice because, on the average, prices advance only about 6 per cent from December 1 to March 1, whereas the loss due to shrinkage and to disease is about 8 per cent. In addition to this, the grower has the extra expense and labor of storage. The West, however, is so far from the great markets that some sort of farm storage is necessary in order to avoid local "slumps" due to dumping all of the crop on a market poorly provided with cars or warehouses. Some sort of central marketing organization is needed to avoid such local congestion, to prevent a general storage at the wrong time, and to encourage one when prices promise materially to advance.

Livermore* made a study of the relation of production to price and found that in seasons of normal production the farm price was about 54 cents a bushel. He gives the following table to show how the production affects price:

* Cornell Rural School Leaflets, Vol. X, p. 151.

Table VII. The Relation of Potato Production in the United States to Fall Price (1866-1916).

Production compared to Normal Per cent	Average Farm price (December 1)
75 or less.....	\$0.94
76 to 85.....	.65
86 to 95.....	.60
96 to 105 (normal).....	.54 (normal)
106 to 115.....	.42
116 to 125.....	.43
over 125.....	.35

Potatoes are so sensitive that seasonal conditions cause the acre-yields to vary widely. The most important single factor in determining the yield of potatoes is therefore at the disposal of neither grower nor buyer. All that can be done is to secure monthly crop estimates from the U. S. Department of Agriculture. Any person may obtain these reports by writing to the Chief, Division of Publications, U. S. Department of Agriculture, Washington, D. C. Careful investigations of the acre-yields and prices have shown that between 1866 and 1917 prices were high when the acre-yields were low, and vice versa. This is not an "average", not a "general statement," but one that expresses the condition each year.

Gilbert* gives the following as the expense of marketing potatoes:

Retailer	15.30 cents
Wholesaler	5-10 cents
Transportation	8-10 cents
Large distributor.....	3- 4 cents
Sacks and car linings.....	3- 5 cents
Local dealer.....	5-11 cents
Total.....	39-70 cents

Transportation charges for the West will be materially higher than those given. Because of this and because of danger from loss in transit, great care should be exercised in grading potatoes for long shipment. Not only should they be graded according to size, but also according to quality. Bruised, frozen, rotten, or otherwise injured tubers should not be included. This is a community problem, because a single grower with a crop bearing blemish will not discard a large part of it on his own initiative. The arrival of a poor lot of potatoes from a locality makes buyers "shy" of all other lots from this community. Here is a field worthy of coöperative effort. Some states have organized potato growers' associations that are giving considerable aid. There is no organization in the West, however, that has done for potatoes

*"The Potato" (Macmillan, 1917), p. 255.

what the California Fruit Growers' Exchange has done for oranges and lemons.

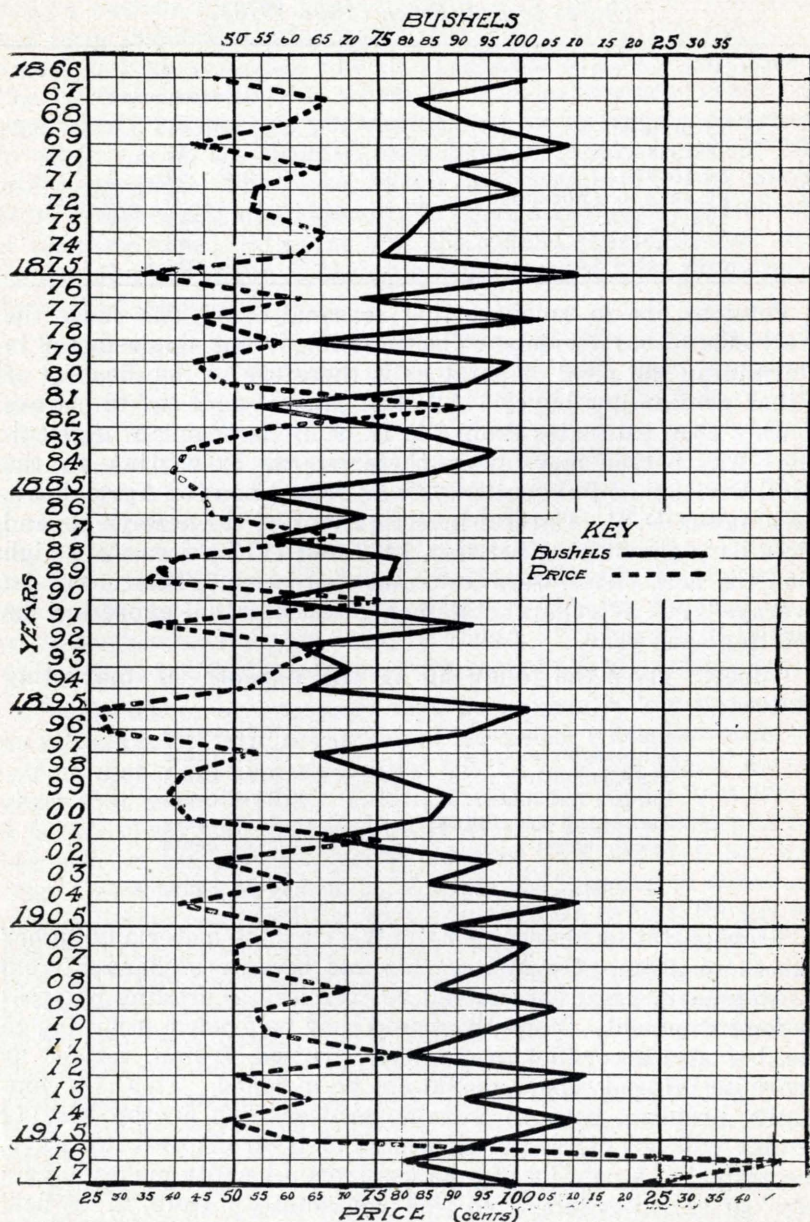


Fig. 20.—Diagram showing the average acre-yield and average farm price of potatoes in the United States from 1866 to 1917. When the acre-yield was high the price was low and when the acre-yield was low the price was high.

UTILIZATION

Potatoes are known to be highly nutritious as food. Their high water content and low protein, however, make them bulky and not adapted to replace meat, milk, eggs, beans, peas, or other foods rich in protein.

Cattle and horses can utilize potatoes in small quantities. The palatability of the raw tubers is not sufficiently great to permit dairy cows to do well on them alone, even for succulence. Up to thirty pounds a day they can be fed to advantage. Horses have been fed half this quantity successfully. Hogs, however, use them to best advantage. When cooked and mixed with grain potatoes are worth about one-fourth as much as grain, pound for pound. The dry matter in potatoes seems therefore to be nearly as good as grain when cooked and fed to hogs along with grain.

SUMMARY

Tho native to America potatoes are now grown in much greater quantities in Europe. A cool, moist climate is largely responsible for Europe's high acre-yields; however, seed selection, thoro rotation, intense cultivation, and the careful use of fertilizers are highly important means of increasing yields. Utah's annual production is about three million bushels; that of the United States is 350 to 400 million bushels.

Potatoes fit into various cropping systems. Where possible at least five or six years should intervene between potato crops on the same land. After alfalfa, after corn planted on alfalfa stubble, after sugar-beets, and after beans are good places to plant potatoes. The application of a farm manure should supplement rotation. Moderate quantities are best except in trucking areas where heavy applications are profitable. Manure is best applied and turned under as early as possible, preferably in the fall or early winter.

Sandy loam soils are best adapted to potatoes. Any of the well-drained soils may be made reasonably good for potatoes by proper manuring, plowing, and harrowing. Gravelly, water-logged, and very compact soils are difficult to handle.

Deep fall or early spring plowing encourages moisture retention and the proper decomposition of organic matter. Frequent harrowings render the seedbed mellow and kill weed seedlings before they can get well established. Well-selected, treated, and carefully cut seed should be planted after the seedbed is clean, mellow, and warm. Cultivation should begin early and

should be of such a nature as to cause the roots to develop deep enough to avoid being cut when the irrigation furrow is made.

Light weekly irrigations are best for small city lots, and three or four rather heavy applications for the field crop except on porous soils where a greater number of lighter applications seem more advisable.

Seed selection is highly profitable. The selection of the best hills and the maintenance of a small seed plat will pay handsomely. Only the best varieties should be grown; under ordinary conditions only one late and one early variety should be grown on any one farm. Rurals and Burbanks are good late types; Early Rose and Early Ohio are good early ones; for medium late potatoes, Cobblers are good.

Careful grading after harvesting is essential either for storage or for market. Higher prices may be expected and cull potatoes are saved for feed on the farm. Good storage is also important to insure safety and convenience. Cellars are better than pits, but pits can be used with safety if wisely constructed. Cellars or pits should be built only where there is good drainage.

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